AD-A120 368 IIT RESEARCH INST CHICAGO IL F/G 9/1
R/M ANALYSIS OF ELECTROMECHANICAL EQUIPMENTS.(U)
MAY 82 J J STEINKIRCHNER F30602-81-C-0046

UNCLASSIFIED RADC-TR-82-141 NL

1 of 2

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: RADC-TR-82-141	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER: AD-A220 368
4. TITLE (and Subtitle): R/M ANALYSIS OF ELECTROMECHANICAL EQUIPMENTS	5. TYPE OF REPORT & PERIOD COVERED: Final Technical Report
	6. PERFORMING ORG. REPORT NUMBER: N/A
7. AUTHOR(s): Joseph J. Steinkirchner	8. CONTRACT OR GRANT NUMBER(s): F30602-81-C-0046
9. PERFORMING ORGANIZATION NAME AND ADDRESS: IIT Research Institute, 10 West 35th Street, Chicago IL 60616	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62702F, 23380263
11. CONTROLLING OFFICE NAME AND ADDRESS: Rome Air Development Center (RBES), Griffiss AFB NY 13441	12. REPORT DATE: May 1982
	13. NUMBER OF PAGES: 175
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Same	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Same

18. SUPPLEMENTARY NOTES

RADC Project Engineer: Anthony N. Ciancio (RBES)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Reliability (R)	Maintainability (M)	Predicted R/M
C^3I System	Maintenance Data System	Demonstrated R/M
Electromechanical Equipments	MIL-STD-781	Field Experience
Ancillary Equipment	Specified R/m	R/M

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the analyses and results of a fourteen-month effort to investigate problem areas and determine the impact of ancillary electromechanical (E/M) equipment on USAF C^3I system reliability and maintainability (R/M). Equipment and system level field experience data were collected and compared with the specified equipment and system level reliability and maintainability (R/M) numerics.

SUMMARY

This report describes the results of a fourteen-month program conducted by IIT Research Insitute (IITRI) to investigate problem areas and determine the impact of ancillary electromechanical (E/M) equipment on USAF C^3I system reliability and maintainability (R/M). The objective of the program was to verify the R/M performance of ancillary E/M equipments in C^3I systems.

The study methodology developed to achieve the goals outlined for this program consisted of six tasks:

- Research and Data Collection
- Selection of equipments to be studied
- Data Summarization and Reduction
- Data Analysis
- Investigation of R/M techniques
- Report Preparation

The data collection effort was comprised of five subtasks - two field surveys using personal interviews and mailed questionnaires, the acquisition of ancillary E/M equipment specifications/standards, the acquisition of C^3I systems R/M reports, the acquisition of field experience data, and the acquisition of other published related literature. The objective of the data collection effort was to obtain the specified and achieved R/M numerics on E/M equipments and C^3I systems.

The selection of the C^3I systems to be studied was based on a six part criteria. The systems selected for study were the AN/TSC-60(V)-1, AN/TSC-60(V)-2, AN/TSC-60(V)-3, AN/TSQ-91, AN/TSQ-92, AN/TSQ-93 and E-3A AWACS. The selection of the ancillary E/M equipments to be studied was limited to power generation, power conversion, environmental control (ECU) and power distribution by agreement of the RADC Technical Monitor.

The analyses was limited by the fact that R/M numerics are not always specified for E/M equipments, and they are not always included in the system level R/M calculations and assessments. The analysis was also limited in that the power generation and power conversion equipments are not included with the system in the USAF Maintenance Data System (MDS) reports, and operating times are not included in the MDS reports. Pseudo R/M numerics were developed to resolve the first two limitations. Two field surveys were utilized to resolve the second two limitations.

The results of the analyses showed that ECU equipments achieve a better R/M than anticipated, power generation and conversion equipments achieve a worse R/M than anticipated, and power distribution equipment may or may not achieve a worse R/M than anticipated (system dependent).

The investigation of R/M techniques resulted in the development of several recommendations that would improve the tracking of future system level and E/M equipment level R/M. The investigation also resulted in the development of a sequential test plan that could be used for demonstrating the reliability of equipments using the Weibull distribution.

PREFACE

This report was prepared by IIT Research Institute for the Rome Air Development Center, (RADC) Griffiss AFB, New York, under Contract Number F30602-81-C-0046, and is submitted in accordance with Contract Data Requirement List Sequence Number A002. The RADC technical monitor for this program was Mr. A. Ciancio (RBES). This report covers the work performed from December 31, 1980 to February 28, 1982.

The principal investigator for this project was Mr. J. Steinkirchner with valuable assistance provided by Mr. B. Arno, Mr. J. Carey, Mr. D. W. Fulton, Mr. W. Kimmel, and Mr. J. Short.

Approved by,

L. Duvall
L. Duvall
Division Director
IIT Research Institute

Prepared by,

J.J. Steinkirchner
J.J. Steinkirchner
Project Manager
IIT Research Institute

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Reliability and Maintainability (R/M) requirements for Command, Control, Communications and Intelligence (C^3I) systems are usually imposed at the system level, and allocated to the electronic equipments/subsystems comprising the system. For the most part, ancillary E/M equipments are not included in the system R/M requirements for a number of reasons: a) they are not considered critical to normal system operation because they are only required during specific modes of operation or under specific operating conditions; b) they are used in a redundant configuration and, thus, have a low probability of failure; c) they operate at a very low duty-cycle relative to the other equipments in the system; d) they comprise such a small proportion of the total system complement (relative to the electronic equipments) that it was felt that their contribution to system R/M is negligible; or e) they are bought "off the shelf" or provided as Government Furnished Equipment (GFE). However, if any one, or several, of the above mentioned reasons, or assumptions, is not true, ancillary E/M equipments having poor R/M can have a significant impact on C^3I system R/M. It has been recently noted that some users of C^3I systems have been experiencing significant R/M problems with ancillary E/M equipments, thus substantiating that a problem exists. This effort investigated the problem areas and determined the impact of the ancillary E/M equipment on the system R/M.

1.1 Objective and Approach

The objective of this study was to verify the reliability and maintainability (R/M) performance of ancillary Electromechanical (E/M) equipments in Air Force Command, Control, Communications and Intelligence (C^3I) Systems. The report includes a data collection and analysis effort designed to determine the actual R/M performance of the ancillary E/M equipments on various C^3I equipments. The actual R/M values are compared to the specified R/M values to determine equipment performance in the field. The R/M values of the ancillary E/M equipment are then compared to the R/M values of the C^3I equipment to determine the R/M impact of the E/M equipment on the C^3I System. This is followed by an investigation of the various methods of modifying existing R/M prediction and demonstration techniques to account for considerations of R/M performance of E/M equipments in the C^3I systems which they support.

1.2 Scope

There are numerous types of C^3I systems in the Air Force inventory. Each system requires various kinds of ancillary E/M equipments. To limit the scope of this report, ancillary E/M equipments were defined as those equipments providing power generation, environmental control and/or electrical power distribution to C^3I systems. The impact of the ancillary E/M equipments on the reliability of C^3I systems was limited to the following equipments: TSC-60(V) 1, 2, 3; TSQ-91, TSQ-92, TSQ-93, and the E-3A aircraft. These systems comprise a significant sample of the current USAF ground mobile and airborne C^3I systems. The ancillary equipment that support these C^3I systems includes both new and mature designs and is representative of the ancillary equipments used with all USAF C^3I systems. A brief description of the equipment studied in the report is provided in the Analysis Section. For more detailed information on the equipments refer to AFCC Pamphlet 100-98 (ref 1) and TAC Pamphlet 55-43 (ref 2).

1.3 Abbreviations

The following abbreviations and symbols are used frequently throughout the report:

A_a	-	Availability (Inherent)
AAA	-	Allocations, Assessments and Analysis
A/C	-	Air Conditioner
AF	-	Air Force
AFALD	-	Air Force Air Logistics Division
AFCC	-	Air Force Communications Command
AFCCP	-	Air Force Component Command Post
AFLC	-	Air Force Logistic Command
AFTO	-	Air Force Technical Orders
AGE	-	Aerospace Ground Equipment
ALC	-	Air Logistics Center
ANG	-	Air National Guard
AN/TSC	-	Tactical Communications Central
AN/TSQ	-	Tactical Operations Center
A_s	-	Availability (Based on number of successful starts)

ASOC	-	Air Support Operations Center
BLIS	-	Base Level Inquiry System
CDR	-	Contract Data Requirement
CRC/CRP	-	Operations Center/Operations Post
C^3I	-	Command Control Communication Intelligence
DTIC	-	Defense Technical Information Center
e	-	base of the napierian logarithm
ECU	-	Environmental Control Unit
E/M	-	Electromechanical
EMU	-	Engine Generator
ESR	-	Equipment Status Report
ETM	-	Elapsed Time Meter
FSC	-	Federal Stock Class
ISSL	-	Initial Supply Support List
m	-	Mean Time Between Failure
MB	-	Engine Generator
MCR	-	Mission Capability Rate
M_{ct}	-	Mean Corrective Maintenance Time
MD	-	Motor Generator
MDS	-	Maintenance Data System
MDT	-	Mean Down Time
MEP	-	Mobile Electric Power
MMC	-	Materiel Management Code
MMHFH	-	Mean Manhours Per Flight Hour
MMHOH	-	Mean Manhours Per Operate Hour
MMMR	-	Mean Maintenance Manhours to Repair
MR	-	Maintenance Ratio
MTBF	-	Mean Time Between Failure
MTBI	-	Mean Time Between Incidents
MTBM	-	Mean Time Between Maintenance
MTBME	-	Mean Time Between Maintenance Events
MTTR	-	Mean Time To Repair
NIIN	-	National Item Identification Number
NMCMR	-	Not Mission Capable Maintenance Rate
NMCOR	-	Not Mission Capable Other Rate
NMCSR	-	Not Mission Capable Supply Rate

NMCTR	-	Total Downtime Percentage
PDN	-	Power Distribution Network
PG	-	Power Generation
RBD	-	Reliability Block Diagram
RMM	-	Reliability Math Model
R/M	-	Reliability and Maintainability
R(t)	-	reliability at time t
t	-	mission length
TAC	-	Tactical Air Command
TACC	-	Tactical Air Control Center
TACS	-	Tactical Air Control Squadron
TCS	-	Tactical Control Squadron
TCTO	-	Time Compliance Technical Order
TD	-	Technician Designator
TIS	-	Tactical Intelligence Squadron
TRC	-	Technology Repair Center
TRS	-	Tactical Recon Squadron
WUC	-	Work Unit Code
χ^2	-	Chi - Square
λ	-	failure rate

2.0 DATA COLLECTION

The data collection effort was approached as a two phased operation. The objectives of phase one were to determine the most widely used ancillary electromechanical (E/M) equipment in C^3I systems, to investigate the problem areas of existing ancillary E/M equipment in USAF C^3I systems, and to assess the availability of failure data for these equipments. Phase one was also tasked with acquiring predicted and specified reliability/maintainability (R/M) values for the equipment. The objective of the phase two effort was to obtain field experience data on the equipment selected during the phase one effort.

2.1 Phase One Data Collection

The phase one effort consisted of:

- an extensive literature search
- a user survey of ancillary E/M equipment
- on-site visits to Air Force equipment users
- collecting Military Specifications and Standards
- a query of non-Air Force equipment users and manufacturers
- locating Air Force data sources

The following is a discussion of each of these efforts

2.1.1 Literature Search

The literature search consisted of an information request to the Defense Technical Information Center (DTIC), a request for manufacturer's R/M reports on C^3I equipment, and various requests for many other reports relevant to the study. The survey of DTIC information requests resulted in acquiring twenty-five reports (ref 3 to 27) which provided insight into possible problem areas of ancillary E/M equipment. The data summarized from the DTIC reports were utilized in the R/M analyses. The request for manufacturer's R/M reports revealed a very limited availability of reports on C^3I systems that also have a significant amount of operating time. R/M reports that contained specified, predicted and assessed R/M numerics were obtained on the TSC-60-1, 2, 3 (ref 28 to 30), the UYK-14B, the TSQ-91, 92, 93 (ref 31, 32), and the E-3A (ref 33 to 35). Many other literature sources were used and are documented in the bibliography.

2.1.2 User Survey Of Ancillary E/M Equipment

A user survey was initiated during the early stages of this project to determine the usage and to identify problem areas with ancillary E/M équipment in the field. The survey was also designed to determine the feasibility of using the AFTO 95 forms for failure data. The questions developed for this survey are:

- What types of ancillary E/M equipment e.g., motor generator, air conditioners, ECU's, heaters, power distribution equipment, teletypes, etc, are used at this station?
  - -- Equipment Nomenclature
  - -- Quantity
- May we have copies of the AFTO 95 forms so that we can record and categorize the number of failures?
- Do the AFTO 95 forms list all of the failures that the equipments have experienced?
  - -- If no, give your estimate of the percentage of total failures that are recorded.
- Record the equipment that this equipment is associated with.
- Please list the serial number, acceptance date, ETM reading on acceptance date, current ETM reading and date taken on the table provided.
- Please describe any reliability/maintainability problem that you believe to be significant. Can you supply other sources of data at your disposal?

This survey was distributed, with a survey from another IITRI project, by mail and in-person. Thirty-eight questionnaires were mailed to active Air Force units, and seventy-seven to Air National Guard units. A list of these units is shown in Table 2.1.2-1. Twenty-nine active Air Force units and four Air National Guard units were visited. The purpose of the visit was to emphasize the importance of the survey and to uncover any ambiguities in the questions asked of the units. A list of units visited is shown in Table 2.1.2-2.

Thirty-six questionnaire forms (31%) were returned. The number of returned questionnaires is well above the 20% average for surveys. A list of the units that returned the completed questionnaire is shown in Table 2.1.2-3.

TABLE 2.1.2-1: UNITS SOLICITED BY MAIL

UNIT	TYPE(1)	LOCATION
2ND CMBTCG	AF	PATRICK AFB FL
5TH CMBTCG	AF	ROBINS AFB GA
10TH TRW	AF	ALCONBURY AB ENGLAND
26TH TRW	AF	ZWEIBRUKEN AB FRG
601ST TCW	AF	SEMBACH AB FRG
600TH TCG	AF	HESSICH-OLDENDORF AS FRG
601ST TCG	AF	RAMSTEIN AB FRG
DET 1 AFCC	AF	APO NY 09021
DET 2 AFCC	AF	OFFUTT AFB NE
DET 3 AFCC	AF	HICKMAN AFB HI
DET 4 AFCC	AF	LANGLEY AFB VA
DET 5 AFCC	AF	ROBINS AFB GA
DET 6 AFCC	AF	WRIGHT-PATTERSON AFB OH
DET 7 AFCC	AF	RANDOLPH AFB TX
DET 8 AFCC	AF	ANDREWS AFB VA
67TH TRW	AF	BERGSTROM AFB TX
728TH TACCS	AF	EGLIN AFB FL
507TH TACCS	AF	SHAW AFB SC
727TH TCS	AF	EGLIN AFB FL
75TH TCF	AF	EGLIN AFB FL
119TH TCF	ANG	ALCOA TN
HQ PACAF	AF	HICKAM AFB HI
162ND CMBTCG	ANG	NORTH HIGHLAND CA
226ST CMBTCG	ANG	GADSDEN AL
201ST CMBTCG	ANG	HICKAM AFB HI
251ST CMBTCG	ANG	SPRINGFIELD OH
252ND CMBTCG	ANG	TACOMA WA
253RD CMBTCS	ANG	WELLESLEY MA
254TH CMBTCG	ANG	GARLAND TX
281ST CMBTCG	ANG	COVENTRY RI
143RD CMBTCS	ANG	SEATTLE WA
147TH CMBTCS	ANG	VAN NUYS CA
148TH CMBTCS	ANG	COMPTON CA
149TH CMBTCS	ANG	NORTH HIGHLANDS CA
201ST CMBTCS	ANG	HILO CA
123RD TCF	ANG	CINCINNATI OH
256TH CMBTCS	ANG	TACOMA WA
261ST CMBTCS	ANG	VAN NUYS CA
263RD CMBTCS	ANG	BADIN NC
265TH CMBTCS	ANG	SOUTH PORTLAND ME
222ND CMBTCS	ANG	COSTA MESA CA
3RD CMBTCG	AF	TINKER AFB FL
223RD CMBTCS	ANG	HOT SPRINGS AR
224TH CMBTCS	ANG	ST. SIMONS ISLAND GA
226TH CMBTCS	ANG	GADSOEN AL
228TH CMBTCS	ANG	KNOXVILLE TN
231ST CMBTCS	ANG	ANDREWS AFB VA
232ND CMBTCS	ANG	MONTGOMERY AL

TABLE 2.1.2-1: UNITS SOLICITED BY MAIL (CONT'D)

UNIT	TYPE	LOCATION
234TH CMBTCS	ANG	HAYWARD CA
242TH CMBTCS	ANG	SPOKANE WA
244TH CMBTCS	ANG	PORTLAND OR
152ND TCG	ANG	ROSLYN NY
154TH TCG	ANG	AURORA CO
157TH TCG	ANG	ST. LOUIS MO
101ST TCS	ANG	WORCESTER MA
102ND TCS	ANG	SLATERSVILLE RI
103RD TCS	ANG	ORANGE CT
105TH TCS	ANG	CHENEY WA
107TH TCS	ANG	PHOENIX AZ
115TH TCS	ANG	DOTHAN AL
116TH TCS	ANG	PORTLAND OR
682TH ASOS	AF	SHAW AFB SC
9TH TIS	AF	SHAW AFB SC
602ND TACCS	AF	BERGSTROM AFB TX
712TH ASOS	AF	BERGSTROM AFB TX
12TH TIS	AF	BERGSTROM AFB TX
HQ ESC	AF	KELLY AFB TX
117TH TCS	ANG	SAVANNAH GA
129TH TCS	ANG	KENNESAW GA
104TH TCF	ANG	KLAMATH FALL OR
HQ AFMMO	AF	WASHINGTON DC
106ST TCF	ANG	SALT LAKE CITY UT
108TH TCF	ANG	HANCOCK FLD NY
109TH TCF	ANG	SALT LAKE CITY UT
110TH TCF	ANG	ALCOA TN
112TH TCF	ANG	UNIVERSITY PARK PA
113TH TCF	ANG	HANCOCK FLD NY
225TH CMBTCS	ANG	GULFPORT MS
182ND CEM SQ	ANG	PEORIA IL
262ND CMBTCS	ANG	BELLINGHAM WA
264TH CMBTCS	ANG	CHICAGO IL
267TH CMBTCS	ANG	WELLESLEY MA
271ST CMBTCS	ANG	ANNVILLE PA
282ND CMBTCS	ANG	COVENTRY RI
240TH CMBTCF	ANG	EASTOVER SC
241ST ATCF	ANG	ST. LOUIS MO
244TH CMBTCF	ANG	PORTLAND OR
269TH CMBTCF	ANG	SPRINGFIELD OH
124TH TCF	ANG	CINCINNATI OH
129TH TCF	ANG	KENNESAW GA
134TH TCF	ANG	FT. DODGE IA
154TH TCF	ANG	COLORADO SPRINGS CO
105TH CEM SQ	ANG	WHITE PLAINS NY
111TH CEM SQ	ANG	WHITE GROVE PA
81ST TCF	AF	KADENA AB JAPAN
507TH TACCS	AF	SHAW AFB SC

TABLE 2.1.2-1: UNITS SOLICITED BY MAIL (CONT'D)

UNIT	TYPE	LOCATION
621ST TCS	AF	OSAN KOREA
6130TH TCF	AF	OSAN KOREA
6140TH TCF	AF	OSAN KOREA
274TH CMBTCS	ANG	ROSLYN NY
283RD CMBTCS	ANG	SAVANNAH GA
240TH ATCF	ANG	EASTOVER SC
242ND ATCF	ANG	SPOKANE WA
254TH CMBTCF	ANG	GARLAND TX
258TH CMBTCF	ANG	ST. CROIX VIRGIN ISLANDS
128TH TCF	ANG	MILWAUKEE WI
133RD TCF	ANG	FT. DODGE IA
138TH TCF	ANG	GREELEY CO
157TH TCF	ANG	ST. LOUIS MO
110TH CEM SQ	ANG	BATTLE CREEK MI
163RD CEM SQ	ANG	ONTARIO GAP CA
6948TH ESC	AF	SAN ANTONIO TX
6922ND ESS	AF	CLARK AB PHILIPPINES
6911TH ESG	AF	HAHN AB FRG
728TH TCS	AF	DUKE FLD FL

Notes: 1) AF - AIR FORCE
ANG - AIR NATIONAL GUARD

TABLE 2.1.2-2: UNITS VISITED

UNIT	TYPE(1)	LOCATION
10TH TRW	AF	ALCONBURY AB ENGLAND
10TH RTS	AF	ALCONBURY AB ENGLAND
1ST RTS	AF	ALCONBURY AB ENGLAND
621ST TCF	AF	WIESBADEN AB FRG
38TH TRW	AF	ZWEIBRUKEN AB FRG
611TH TCF	AF	ALZEY AS FRG
603RD TCS	AF	ALZEY AS FRG
601ST TCG	AF	RAMSTEIN AB FRG
728TH TCS	AF	EGLIN AFB FL
727TH TCS	AF	EGLIN AFB FL
5TH TAIRCG	AF	OSAN AB KOREA
604TH DASS	AF	CAMP RED CLOUD KOREA
267TH TCS	ANG	WELLESLEY MA
22AF/DOV	AF	(2)TRAVIS AFB CA
MOTBA	A	(2)OAKLAND ARMY BASE CA
USA ALC	A	(2)TOBYHANNA PA
629TH TCF	AF	SCHWELENTRUP FRG
626TH TCF	AF	NORDHOLZ FRG
619TH TCF	AF	SCHWELENTRUP FRG
606TH TCS	AF	BREMERHAVEN FRG
SEA LAND	C	(2)OAKLAND CA
USA ALC	A	(2)SACRAMENTO CA
1ST CMBTCS	AF	LINDSEY AS FRG
38TH TRS	AF	ZWEIBRUKEN AB FRG
26TH TRW	AF	ZWEIBRUKEN AB FRG
622ND TCF	AF	RHEIN GRAFFENSTEIN AS FRG
600TH TCG	AF	HESSICH-OLDENDORF AS FRG
601ST TCW	AF	SEMBACH AB FRG
75TH TCF	AF	EGLIN AFB FL
271ST CMBTCS	ANG	INDIAN TOWN GAP PA
621ST TCG	AF	OSAN AB KOREA
1961ST CMBTCG	AF	CLARK AB PHILIPPINES
101ST TCS	ANG	WORCESTER MA
USAF ALC	AF	(2)MC CLELLAN AFB CA
162ND CMBTCS	ANG	ROBINS AFB GA
636TH TCF	AF	NORDHOLZ FRG
609TH TCF	AF	HESSICH-OLDENDORF FRG

NOTES:

1) AF - AIR FORCE
   ANG - AIR NATIONAL GUARD
   A - ARMY
   C - COMMERCIAL
2) TERMINAL POINTS

TABLE 2.1.2-3: UNITS RESPONDING

UNIT	TYPE(1)	LOCATION
507TH TACCS	AF	SHAW AFB SC
727TH TCS	AF	EGLIN AFB FL
253RD CMBTCS	ANG	WELLESLEY MA
256TH CMBTCS	ANG	TACOMA WA
263RD CMBTCS	ANG	BADIN NC
265TH CMBTCS	ANG	SOUTH PORTLAND ME
3RD CMBTCG	AF	TINKER AFB OK
223RD CMBTCS	ANG	HOT SPRINGS AR
226TH CMBTCS	ANG	GADSDEN AL
234TH CMBTCS	ANG	HAYWARD CA
244TH CMBTCS	ANG	PORTLAND OR
103RD TCS	ANG	ORANGE CT
105TH TCS	ANG	CHENEY WA
107TH TCS	ANG	PHOENIX AX
682TH ASOS	AF	SHAW AFB SC
9TH TIS	AF	SHAW AFB SC
129TH TCS	ANG	KENNESAW GA
104TH TCF	ANG	KLAMATH FALL OR
264TH CMBTCS	ANG	CHICAGO IL
271ST CMBTCS	ANG	ANNVILLE PA
282ND CMBTCS	ANG	COVENTRY RI
244TH CMBTCF	ANG	PORTLAND OR
105TH CEM SQ	ANG	WHITE PLAINS NY
111TH CEM SQ	ANG	WHITE GROVE PA
81ST TCF	AF	KADENA AB JAPAN
621ST TCS	AF	OSAN KOREA
6130TH TCF	AF	OSAN KOREA
128TH TCF	ANG	MILWAUKEE WI
138TH TCF	ANG	GREELEY CO
157TH TCF	ANG	ST. LOUIS MO
6948TH ESC	AF	SAN ANTONIO TX
6922ND ESS	AF	CLARK AB PHILIPPINES
6911TH ESG	AF	HAHN AB FRG
10TH RTS	AF	ALCONBURY AB ENGLAND
27TH TCS	AF	EGLIN AFB FL
5TH TAIRCG	AF	OSAN AB LOREA
604TH DASS	AF	CAMP RED CLOUD KOREA

Notes: 1) AF - AIR FORCE
ANG - AIR NATIONAL GUARD

2.1.3 On-Site Visits Of Air Force Equipment Users

Five visits were made to Air Force units during the early stages of this project. The objective of the trips was to gain field knowledge on the usage, maintenance procedure, record keeping and areas of user concern associated with ancillary E/M equipment. The following is a list of the places visited:

- Wellesley ANG, MA
- SM-ALC, Sacramento, CA
- Eglin AFB, FL
- Griffiss AFB, NY
- Langley AFB, VA

The information provided at these locations is described in the following paragraphs.

Wellesley ANG Base provided usage information in terms of operating time since acceptance on various types of engine-generator sets on the 407L system. They indicated failure data for their equipment could be obtained from AFM/66-1 records. Failure count information on ECUs was also obtained.

Sacramento Air Logistics Center (SM-ALC) personnel stated that a very high level of maintenance is authorized to be performed in the field on engine generators. The result is that depot maintenance has all but been eliminated. For example, out of 545 A/E24U-8 turbine generators that have been procured only 8 were returned to AFLC for rehabilitation in 1980. SM-ALC did not know how much logistic support is procured directly by TAC elements from contractors or vendors using locally available funds.

The result is that parts consumption data generated by AFLC on engine generators does not reflect the total part consumption. The SM-ALC Material Management and Maintenance personnel believe that if valid R/M data are to be acquired, it will have to come from field operational units.

The Sacramento Material Management and Maintenance personnel informed us that the A/E24U-8 turbine generators have never been used as was originally intended, i.e., for interim power until diesel driven generators were brought on-line. They also said they believe that the gas turbine has the greatest impact on reliability of the A/E24U-8; however, they have no data to support their belief. The A/E24U-8 receives extensive field maintenance and repair.

Eglin AFB personnel stated that frequent engine changes on A/E24U-8 sets can negate the value of elapsed time meter readings. Eglin personnel also reported that air conditioner parts are hard to obtain and can result in a TSC-60 unit being off the air because of inoperative air conditioning. The trip also provided insights into common and uncommon maintenance procedures used on generators and ECUs.

Griffiss AFB Civil Engineering (CE) personnel reported that they maintain paper records on the 60 Hertz emergency generators on the base. SAC personnel reported that all data on the 400 Hertz generators used to power aircraft on the ground are reported through the SAC computer. These data are available; however, elasped time meter readings are ordinarily lost during computerization of the records.

2.1.4 Military Specifications And Standards

An effort was undertaken to obtain all military specification and standards applicable to ancillary E/M equipment used with C^3I systems. The purpose was to establish the specified R/M requirements of the equipment to be studied. Table 2.1.4-1 contains a list of relevant specifications and standards identified and obtained.

TABLE 2.1.4-1: MILITARY SPECIFICATION/STANDARD

Spec/STD Number	Date	Name
MIL-A-38269E	Feb 75	Air Conditioner, A/E32C-17
MIL-A-38339D	Mar 70	Air Conditioners, Lightweight, Compact, Military
MIL-A-38340C	Nov 77	Air Conditioner, A/E32C-18
MIL-A-38345D	Feb 70	Air Conditioner, A/E32C-24
MIL-A-38346D	Dec 78	Air Conditioner, A/E32C-25
MIL-A-38347D	Feb 70	Air Conditioner, A/E32C-26
MIL-A-38348C	Jan 70	Air Conditioner, A/E32C-27
MIL-A-52767B	Sep 79	Air Conditioners: Vertical and Horiztonal, Compact
MIL-A-83380	Feb 79	Generator Sets, Gas Turbine Engine Driven, 30 and 60KW, 400HZ
MIL-G-6162B	Feb 72	Generator and Starter - Generator, Electric Direct Current, Nominal 30 volts, Aircraft
MIL-G-21480	Jul 58	Generator System, Single Generator, Constant Frequency Alternating Current, Aircraft, Class C
MIL-G-26727D	Jun 74	Generator Sets, Diesel Engine, 15KW thru 150KW, 50/60 Hertz, Type I (Tactical Class 2 (Utility)
MIL-G-28670	Apr 74	Generator Set, Gas Turbine Engine, 750 KW, 50/60 Hertz, Prime, Utility.
MIL-G-38195C	Jul 78	Generator Set, Gas Turbine Engine, 60KW, 400 Hertz, General Purpose
MIL-G-38441C(USAF)	Aug 71	Generator Sets, Diesel Engine EMU-19/U, EMU-20/U, EMU-21/U, EMU-22/U, EMU-23/U, EMU-24/U, 400 cycle Output, Multi-Installation

TABLE 2.1.4-1: MILITARY SPECIFICATION/STANDARD (CONT'D)

Spec/STD Number	Date	Name
MIL-G-52732	Jun 72	Generator Sets, Gasoline Engine Driven, 5KW thru 10KW, 60 Hertz, 400 Hertz and 28 Volt Direct Current, Type I (Tactical, Class 2 (Utility)
MIL-G-52884	Mar 81	Generator Sets, Diesel Engine Driven, 15 thru 200 Kilowatts, 50/60 and 400 Hertz, (Tactical)
MIL-G-52889B	Nov 78	Generator Sets, Diesel Engine Driven 5 and 10KW, 60 Hertz (Tactical) (Utility)
MIL-M-4803D	May 77	Motor-Genertor, 400 HZ Precise Output
MIL-M-4818D	Jul 79	Motor-Genertor, Skid Mounted, Type MD-2
MIL-M-4820E	Jul 79	Motor-Generator, Skid Mounted, Type MD-4
MIL-STD-633E	Feb 80	Mobile Electric Power Engine Generator Standard Family MEP-404A, 60KW, 400Hz, Gas Turbine Engine Driven Generator Set Characteristics
MIL-STD-705B	Jun 72	Generator Sets, Engine Driven Methods of Tests and Instructions
MIL-STD-1332B	Mar 73	Definitions of Tactical, Prime, Precise, and Utility Terminologies for Classification of the DoD Mobile Electric Power Engine Generator Set Family
MIL-STD-1408A	Apr 75	Air Conditioners, Family of Environmental Control Units, General Application Characteristics
MIL-STD-1650	Jun 74	DoD Standard Family of Aircraft Ground Support Power Units

2.1.5 Non-AF Users And Manufacturers

A list of non Air Force users and manufacturers of E/M equipments that are similar to that associated with C^3I systems was made. These users and manufacturers were contacted to establish if they had any usable data. In some cases these data were available; however, in all cases the data were not germane to the study. The following is a list of non Air Force users and manufacturers contacted:

- Keco Industries, Cincinnati, OH
- American Air Filter, St Louis, MO
- Trane Co, LaCrosse, WI
- D. Wedj, Inc, York, PA
- Tobyhanna Army Depot
- Naval Air Station, Norfolk, VA
- HQ US Marine Corps Integration and Logistic Dept.
- Naval Sea Systems Command, Washington, D.C.
- Solar Division of International Harvester
- Paison & Peebles, Division of NE Engineering Industries
- Southwest Research Institute (SWRI)
- Babcock & Wilcox, Lynchburg, VA
- B.B. Saxon, San Antonio, TX

2.1.6 Locating Air Force Data Sources

An extensive effort was made to locate and obtain samples of available Air Force generated R/M data on C^3I systems and associated ancillary E/M equipments. The objective of the effort was to establish the availability of useful data to be used during the analysis portion of the report. The managing Air Logistic Centers (ALC) were contacted as well as individual Units and Commands. Air Force Communications Command (AFCC) was also contacted as a possible data source. The following is a list of the Air Force and Air National Guard (ANG) data sources contacted and the information and/or data received:

SOURCE	INFORMATION RECEIVED
San Antonio ALC (managing center for ECUs, FSC 4120)	- Their Data collection and Analysis Component cannot supply failure data on ECUs - No Initial Spare Support Lists (ISSL) available for FSC 4120 type air conditioners - ECU repairs are contracted to B.B. Saxon Inc.

SOURCE	INFORMATION RECEIVED
	- No repair data available on the EMU-30's turbine engine - No records available on procurement of parts or repair to ECUs - Available R/M data received on FSC 4120 ECUs
Warner Robins ALC (managing center for Heaters, FSC 4520)	- No failure information available on FSC 4520 heaters
Sacramento ALC (managing center for Motor and Engine Driven Generator, FSC 6115 and FSC 6125)	- A/E 24U-8 Depot does not use AFM 66-1 reporting - ISSLs were received for the A/E 24U-8 and MD-4 - They have no data on failure - They cannot supply procurement data on parts because parts are purchased locally or from other agencies
Tinker AFB, OK	- Acquired 407L R/M Index. It is derived from AFM 66-1. It does not contain generator set data. Some ECU maintenance data are listed
TAC Headquarters	- Obtained 407L Base Level Inquiry System (BLIS) covering all TAC Bases - Informed that no correlation can be expected between Equipment Status Report (ESR) data and MDS BLIS information
602 TAC Wing Bergstrom AFB, TX	- No BLIS available. All reports must come from TAC HQ
507 TACC Wing Shaw AFB, NC	- No BLIS available. All reports must come from TAC HQ
AFCC, Scott AFB, IL	- BLIS reports not available because of damage to Maintenance Data System (MDS) files - ESR data are not collected on the A/E 24U-8, MD-4 and 13 other common generator sets - ESR data are not collected on the A/E32C-24 and A/E32C-26 - In general ESR data are collected against missions and not systems
601 TCW Sembach AB, FRG	- They maintain 24 hours a day operation on A/E24U-8 generator, but they did not supply data
USAFE (eight selected bases)	- Report they are unable to provide a BLIS with information on generators sets and ECUs
552 AWACWC Tinker AFB, OK	- Received BLIS report on airborne generator and flightline ground power equipment - Informed that only two inflight AC power failures listed in one year for entire fleet

SOURCE		INFORMATION RECEIVED
	-	Received estimate of ground maintenance time per flight hour
	-	Received mission abort criteria for some systems from E3A flying squadron
AF Electronic Security Command	-	Only two COMPASS EARS systems procured
101 TCS Worchester ANG, MA	-	Obtained list of High 25 reports for A/E24U-8 and other equipment. The High 25 report lists the 25 ANG equipments with the greatest number of maintenance actions during the reporting period
152 TCG Roslyn ANG Long Island, NY	-	Requested Latest High 25 report, but did not receive
Headquarters ANG	-	Informed High 25 report is not sent to HQ. The report is a unit option so each unit must be contacted separately.

2.2 Phase Two Data Collection

The objective of the phase two effort was to secure failure data on specific C^3I systems and their associated ancillary E/M equipments. As efforts proceeded in phase two, several decisions were made concerning the scope of this report. All Ground Fixed C^3I systems, i.e., COBRA DANE, PAVE PAWS, etc., were eliminated from the study by the RADC technical monitor. It was felt that it would be more effective to concentrate on mobile and airborne systems because of the commonality of ancillary equipments. As a result all efforts to obtain data on ground fixed systems were terminated. The ground mobile systems selected for analysis were the TSC-60(V), TSQ-91, TSQ-92, and TSQ-93. The AWACS was selected as the airborne system. During a meeting with the technical monitor an agreement was made to study only the ancillary E/M equipment providing power generation, power distribution and environmental control for the selected ground mobile and airborne systems.

A concentrated data collection effort was initiated for those systems and equipments selected for the study. Because of the nonavailability of data from non Air Force sources discovered during phase one, the decision was made to attempt to maximize available Air Force sources. This involved an exhaustive search into the various Air Force Data Systems for useful failure data. To provide another source of failure data independent of the Air Force System, a second survey was initiated in order to gain failure data direct from the field.

2.2.1 Air Force Data

Several efforts were made to secure useful Air Force data. The Maintenance Data System (MDS) was used to acquire numerous reports for analysis. Equipment Status Reports (ESR) were requested and received on several equipments. An attempt was also made to correlate parts procurement into failure information. The following is a description of these efforts.

MDS Reports The Air Force MDS is the data base for numerous reports. The data summarized on these reports are designed to meet the specific needs of the Air Force user. AFLCR 66-15 (ref 36) lists the reports derived from MDS data that are available from the responsible AFLCs. The reports of specific interest to this study are part of the D056B series, On-Equipment Maintenance Data Reports. On-equipment maintenance is maintenance actions accomplished on complete end articles of equipment. This includes support general work (accomplishment of scheduled and special inspections), removal and replacement of components, and fix-in-place repair actions. Off-equipment maintenance, D056C series, is in-shop maintenance performed on removed components. The D056C series was examined and considered too specific for the scope of this report. The D056B series does provide the general system data required. The following is a description of the MDS derived reports used in this report.

Detail Maintenance Actions For Selected WUCs (D056B5503): This report provides from 1 to 12 months detail maintenance data on selected WUCs by how malfunction code, action taken code, base, and serial number for specific WUCs on an end article.

Maintenance Actions, Manhours, and Aborts By Work Unit Code (D056B5006): This report provides on-equipment and off-equipment historical information on the maintenance actions, manhours, and aborts for the past 6 months by month on every WUC included in the master record. In addition, a summary line for each subsystem and system shows totals of this data by month. Due to the method of assigning and reporting equipment classification codes for registered AGE, off-equipment data cannot be displayed in AGE reports.

Summarized Maintenance Actions For Selected Work Unit Codes (D056B5505): This report provides 6 months of summarized detail information on WUCs which do not perform to preset standards. The data is presented in three parts for each WUC. Part I, On-Equipment Actions; Part II, Shop Action; Part III, Parts Replacement (Parts II and III are not reported for AGE not having unique equipment classification).

Selected Part Number Action Summary (D056C4402): This report is a summary or history type report showing a maximum of 12 months and a minimum of 1 month of maintenance and repair data reported by AF bases and AFLC Technology Repair Centers (TRCs). The report reflects action taken (for the time period covered) on items identified by part number within NIIN within MMC within FSC.

Maintenance Action For Selected NIIN Numbers (D056C403): This report provides 6 months of off-equipment detail data on a specific item reflecting application, location, how malfunction codes, and action taken codes. The report is laid out in three parts; Part I, Malfunction and Action Taken Summary; Part II, No Defect Actions, and Part III, Action summary by Base. The report is sequenced by part number within NIIN within MMC within FSC within Technician Designator (TD) and ALC management division.

Parts Replaced During Field or Depot Repair (D056C4404): This report provides 6 months of detailed maintenance data on those parts (bits and pieces) replaced on a component repaired at bench check, in field maintenance shops, by a TRC or contractor. These are all parts as shown in Block 20, AFTO

Form 346, "Maintenance Discrepancy/Production Credit Record and Master Card," and Block 29, AFTO Form 349 that can be related to the component being repaired by matching job control numbers, equipment classification, and WUC.

Reliability and Maintainability Index, E-3A: (ref 37) Special study by Oklahoma City ALC using MDS data from AFTO 349 cards. The following data elements are reported for each WUC: Failure, MTBF, Maintenance Action, Mean Time between Maintenance (MTBM), Maintenance Manhours, Maintenance Manhours per 100 Operating Hours, Special Inventory, and Failure Rate.

Base Level Inquiry System (BLIS) Reports: These reports contain the raw data as reported on the AFTO 349 forms. Operating times are not reported on these reports.

AFALD 800-4 Manual: (ref 38) This manual lists maintenance events for each system 2 digit work unit code (WUC) of the aircraft. The maintenance events for each system are further divided into inherent events, induced events, and no defect events. Inherent events are activities resulting from failures occurring internal to the equipment. Induced events are activities resulting from failures caused by external sources. No defect events are activities, other than preventive maintenance associated with the removal and replacement of items later found to be serviceable. Maintenance manhours are also listed for each type event. The manual contains data over the entire life of the aircraft.

Equipment Status Reports (ESR) ESRs were received from TAC on the TSC-60, TSQ-91, TSQ-92, TSQ-93 and the A/E24U-8. ESRs were not available on the E-3A or the other ancillary E/M equipments being studied. We were informed that ESRs are only reported on selected equipment which have current command interest. TAC also provided their "Production Analysis Summary" (ref 39). It is a monthly publication which summarizes ESR data by month and fiscal year. The publication reports equipment mission capability for all TAC units combined. The not-mission-capable-time is identified as due to maintenance, supply or other. The times listed are percentage of calendar time that the equipment was in that state. The following table is a summary of the Production Analysis Summaries from October 1980 to September 1981:

EQUIP	QTY/EQ HOURS	COMMAND	MCR	NMCMR	NMCSR	NMCOR	NMCTR
TSC-60	13/113880	TAC 83.9	84.2	3.2	10.2	2.4	15.8
TSC-91	5/43800	TAC 89.3	87.8	8.5	3.3	.4	12.2
TSC-92	3/26280	TAC 95.8	95.8	4.2	0	≈0	4.2
TSC-93	4/35040	TAC 89.3	89.2	8.1	.8	1.9	10.8
A/E24U-8	112/960576	TAC 95.9	97.1	1.4	.9	.6	2.9

MCR - Mission Capability Rate (analogous to availability)
NMCMR - Not Mission Capable Maintenance Rate
NMCSR - Not Mission Capable Supply Rate
NMCOR - Not Mission Capable Other Rate
NMCTR - Total Downtime Percentage
QTY/EQ - Quantity of Equipments/Total Equipment Operate Hours

Supply Lists: An Initial Supply Support List (ISSL) (ref 40) was obtained on the MD-4 and the A/E24U-8 in an attempt to establish a failure rate using parts replacement data. The ISSL is a list of parts for a specific equipment which are authorized to be ordered through the base supply system.

2.2.2 Survey

The second survey of this project was a three month effort whose purpose was to gain failure data direct from the equipment users. Eleven units were contacted in-person about the survey. Each unit was instructed on the mechanics of filling out the form and given a detailed briefing on the overall objective of the project.

The survey consisted of two separate forms: Generator Maintenance Data Survey; and Environmental Control Unit (ECU) Maintenance Data Survey (See Appendix A). Both the generator and ECU forms required that specific questions be answered about each failure in order to gain reliability, maintainability and system availability information about the equipment. The survey form also required that all non-standard operating procedures and/or conditions be recorded on the forms. To help insure completeness of the survey, each unit was contacted by telephone or in-person prior to their submitting the surveys. At that time questions were answered and unclear responses clarified. Table 2.2.2-1 lists the units that were contacted and the quantity and type of equipments involved in the survey.

TABLE 2.2.2-1: GENERATOR AND ECUs SURVEYS

UNIT CONTACTED	SURVEY REQUESTED ON NUMBER/TYPE EQUIP	SURVEY RECEIVED ON NUMBER/TYPE EQUIP
3rd Combat Communication Group (LGM-3) (AFCC) Tinker AFB, OK	16/EMU-19 25/MEP-005A 7/MEP-006A	25/MEP-005A 7/MEP-006A
712 ASOC Bergstrom AFB, TX	6/A/E24U-8 1/MD-4 3/ECUs	6/A/E24U-8 1/MD-4 4/ECUs
12 TIS Bergstrom AFB TX	2/MB-15 2/MD-4 13/ECUs	2/MB-15 3/MD-4 1/MD-2 14/ECUs
602 TACS Bergstrom AFB, TX	2/MD-4 16/A/E24U-8 36/ECUs	15/A/E24U-8 37/ECUs
12 TRS Bergstrom AFB, TX	6/MB-15 25/ECUs	6/MB-15 19/ECUs
91 TRS Bergstrom AFB, TX	6/MB-15 25/ECUs	6/MB-15 24/ECUs
728 TCS Duke Field Eglin AFB, FL	16/A/E24U-8 3/MD-4 12/A/E32C-27 10/A/E32C-25 8/A/E32C-23 4/A/E32C-18	14/A/E24U-8 1/MD-4 9/A/E32C-27 5/A/E32C-25 1/A/E32C-23 3/A/E32C-18
727 TCS (T) Hurlburt Field Eglin AFB, FL	10/A/E24U-8 9/MD-4 12/A/E32C-27 10/A/E32C-25 8/A/E32C-18	10/A/E24U-8 10/MD-4 8/A/E32C-27 5/A/E32C-25 3/A/E32C-18
507 TACC Shaw AFB, SC	14/A/E24U-8 16/A/E32C-27 9/A/E32C-25	17/A/E24U-8 11/A/E32C-27 12/A/E32C-25
9 TIS Shaw AFB, SC	4/MB-15 2/MD-4 14/A/E24U-8	3/MB-15 2/MD-4 1/MD-2 15/ECUs

TABLE 2.2.2-1: GENERATOR AND ECUs SURVEYS (CONT'D)

UNIT CONTACTED	SURVEY REQUESTED ON NUMBER/TYPE EQUIP	SURVEY RECEIVED ON NUMBER/TYPE EQUIP
62 TRS Shaw AFB, SC	6/MB-15 25/ECUs	6/MB-15 27/ECUs
682ASOC Shaw AFB, SC	6/A/E24U-8 1/MD-4 4/ECUs	6/A/E24U-8 4/ECUs

3.0 ANALYSIS

3.1 Selection Of Equipments

Selection of the equipments to be studied in this report was based on the following factors: a qualifying system must have adequate failure data available; the specified, predicted and demonstrated R/M values must be available in a form which will allow comparison with observed results; the selected systems must also use a variety of ancillary E/M equipments; the E/M equipments of interest are those which provide electrical power generation, electrical power distribution, and environmental control; the selected equipments come from different environments (i.e., Ground Mobile and Airborne) and be used in several different locations; and each selected system's demands of its ancillary equipment be different from the other selected systems.

The preliminary analysis revealed that the following systems met the selection criteria: TSC-60(V), TSQ-91, TSQ-92, TSQ-93 and the E-3A aircraft. These systems have the greatest amount of available field experience data which can be compared to the specified, predicted and demonstrated R/M values. The systems also use several types of ancillary equipments. The following is a list of the ECU and power equipments associated with the selected equipments:

	TSQ-91	TSQ-92	TSQ-93	TSC-60(V)	E-3A AWACS
MD-4	X(3)	X(3)	X(2)	X(3)	
EMU-12E			X		
EMU-21		X	X	X(1)	
EMU-22		X		X	
A/E24U-8	X(3)	X(3)	X(6)	X(10)	
MB-15	X(1)		X	X(5)	
MEP-005				X(1)	
MEP-006				X(3)	
A/E32C-24				X(8)	
A/E32C-25				X(8)	
A/E32C-27	X(2)	X(1)	X(2)	X(1)	
MEP-116A					X

The number in the columns corresponds to the number of surveyed units that use that combination of equipments. This information was taken from survey number one.

The TSC-60(V), TSQ-91, TSQ-92, and TSQ-93 are all ground mobile systems. The TSC-60(V) is designed to be remotely operated and controlled; therefore, its ancillary equipments are not required to support personnel. The TSQ-91, 92 and 93 are designed to provide housing for numerous personnel performing a command and control function in support of tactical air operations in the field. The E-3A is the airborne system. It is the most complex system considered in this study. It has undergone the greatest amount of testing as a complete unit when considering the basic aircraft as ancillary to the mission systems. The following is a brief description of the selected C^3I systems and their ancillary E/M equipments. For more detailed information refer to AFCC Pamphlet 100-98 (ref 1) and TAC Pamphlet 55-43 (ref 2).

AN/TSC-60(V)-1

The AN/TSC-60(V)-1 Communications Central is an HF/SSB radio housed in an air conditioned shelter. Two 1 KW transmitters, receivers and associated equipment provide voice, CW, teletype or high speed data, multiplexed teletype and speech-plus-teletype signals.

AN/TSC-60(V)-2 & 3

AN/TSC-60(V)-2 and OZ-11/TSC-60(V)-2, which make up the AN/TSC-60(V)-3, Communications Central, are transportable HF SSB communications centrals. They provide point-to-point and ground-to-air communications using two independent radio groups consisting of two 2.5 KW transmitters and two radio receivers. Each radio group provides four 3 KHz independent sideband (ISB) channels with a transmit capability of 2.5 KW (PEP/average) power output. The radio equipment is automatically tuned and operates in the 2 to 30 MHz frequency range in either simplex or duplex mode.

AN/TSQ-91

The CRC/P Operations Center, when integrated with the AN/TPS-43 radar, functions as the major weapons control agency of the TACS by performing all functions of surveillance and weapons control in its assigned area of tactical responsibility. Modular in design, the CRC/P is capable of adjusting to the needs of a given deployment by additions/deletions to the basic set of the following modules: Group Display, Console, Data Processing, Ancillary Equipment, and Air Conditioning.

AN/TSQ-92

The TACC is the command action arm of the Tactical Air Control System. Necessary facilities are provided to perform the Combat Operations and Combat Plans functions of the Air Force Component Command Post (AFCCP). Unlike the CRC/CRP, the TACC is essentially a manual operation; it consists of desk positions, manually posted plotting displays, and communications equipment necessary to support personnel in the accomplishment of the Tactical Air Control

Mission. Like the CRC/CRP the TACC is modular in design; capable of adjusting to the needs of a given deployment by a building-block approach to the basic set of the following modules: Group Display, Furnishings, and Air Conditioning.

AN/TSQ-93

The primary purpose of the ASOC is to provide fast reaction to ground force requirements for Tactical Air Support. Working in close coordination with Army personnel, ASOC personnel provide the focal point for information exchange, coordination, and allocation of sorties provided by the TACC to fulfill Army requirements. Like the TACC, the ASOC is essentially a manual operation; it consists of desk positions, manually posted map displays and communications equipment necessary to support personnel in their performance of the assigned mission. Modular is design, the ASOC is comprised of three unique modules; the Operations Module, Air Conditioning Module, and the Communications Center.

E-3A

The E-3A Sentry, Airborne Warning and Control System (AWACS) aircraft is a long-range radar platform providing air surveillance in all weather and above all kinds of terrain. The E-3A has a data storage and processing capability, can provide real-time assessment of enemy actions, and can display status and position of friendly resources. The E-3A performs a dual role: (1) a Command and Control Center to support quick reaction deployment and Tactical Air Operations by TAF units, and (2) a survivable early-warning airborne command and control center for identification, surveillance and tracking of enemy forces. The aircraft also provides command and control in the NORAD environment. The E-3A crew consists of 17 aircrew members; 4 flight and 13 mission crew.

A/E 24U-8

The A/E 24U-8 is a transportable 60/120 KW, 400 Hz power plant consisting of two fully-equipped EMU-30/E gas turbine generators and associated distribution equipment mounted on a pallet. The power plant will operate in all-weather and all global environmental conditions for extended periods. One generator will automatically start if the other one degrades. The EMU-30/E is currently being replaced by the MEP-404A.

MB-15

The MB-15 consists of an engine, generator group, control system, winterization system, and housing equipment. The unit is designed to operate in all types of weather. The generator is directly coupled to a diesel engine (6-cylinder (International Fermont) 4-cycle, liquid-cooled, turbo-charged). The MB-15 is a skid-mounted generator set. Wheels can be mounted to the skid.

MD-4

The MD-4 is a skid-mounted motor-driven generator set designed for permanent or semi-permanent installation. The purpose of this unit is to convert 60 cycle AC power to 400 cycle AC power. Power to turn the generator is furnished by a 6-pole synchronous AC motor. The set operates on an input power of 220VAC, 3-phase, 60 Hz or 440VAC, 3-phase, 60 Hz.

MEP-005A/MEP-006A

The MEP-005A and MEP-006A are self-contained, wheel or skid-mounted power unit used for electronic and navigational equipment. The engine is a liquid-cooled, 6-cylinder, valve-in-head, 4-stroke cycle, turbo-charged, diesel engine. To extend their capabilities, the sets are designed to accept and operate with the following kits: load bank, fuel burning or electric winterization, wheel-mounting, automatic transfer panel 50/60 Hz, remote control box, auxiliary fuel burning or electric winterization kit.

EMU-21/EMU-22

The EMU-21 and EMU-22 are transportable, trailer-mounted, power facilities designed to furnish alternating current for electronic and navigational equipment. The generator is coupled to a Monarch diesel engine, Model CSR-3. The engine is an air-cooled, 3-cylinder, 4-cycle type. They are equipped with a 24V electrical starting system. The engine speed is controlled by an electronic governor. The units are designed to operate at -65°F to +125°F at sea level and -65°F to +75°F at 8,000 feet. They have an integral heating system, battery system, engine operation control panel, and generator instrument and control panel. A towing facility is provided.

A/E32C-18

The A/E32C-18 is designed to provide ventilation, cooling, heating, pressurization, filtering and dehumidification to meet electronics and personnel environmental control. This unit is self-contained.

A/E32C-23

The A/E32C-23 is designed to provide ventilation, cooling, heating, pressurization, filtering, and dehumidification to meet electronics and personnel environmental control requirements. This unit is self-contained. It supports the following equipment: AN/TRC-97, AN/TSC-15 and S-280 Maintenance Shelter.

EMU-12E

The EMU-12E is a transportable 30KW, 400HZ, Precise, Tactical turbine generator set mounted on a skid. The generator will operate in all-weather and all global environmental conditions for extended periods.

MEP-116A

The MEP-116A is a mobile 100KW, 400HZ, skid-mounted diesel generator set used to provide ground electrical power for the E-3A AWACS.

A/E32C-24

The A/E32C-24 is designed to provide ventilation, cooling, heating pressurization, filtering, and dehumidification to meet electronics and personnel environmental control requirements. This unit is mounted on the pallet assembly and supports the following equipment: AN/TSC-62, AN/TGC-27, AN/TSW-7, AN/TSC-60(V)-1 and AN/TPN-19.

A/E32C-25

The A/E32C-25 is designed to provide ventilation, cooling, heating, pressurization, filtering, and dehumidification to meet electronics and personnel environmental control requirements. This unit is mounted on the pallet assembly and supports the following equipment: AN/TSC-62, AN/TGC-27, AN/TSC-60(V)-1, AN/TGC-27 and AN/TGC-28.

A/E32C-27

The A/E32C-27 is designed to provide ventilation, cooling, heating, pressurization, filtering, and dehumidification to meet electronics and personnel environmental control requirements. This unit is mounted on the pallet assembly and supports the following equipment: AN/TSQ-91(V), AN/TSQ-92(V) and AN/TSQ-93(V).

3.2 Evaluation Of Data Sources

This section provides an in-depth evaluation of the field experience data sources utilized to derive the achieved R/M numerics.

3.2.1 Air Force

Maintenance Data System: The Air Force, under Regulation 66-1 and 66-5, established the Maintenance Data System (MDS) to provide for the recording, storage, and retrieval of information concerning action taken by field maintenance personnel to keep Air Force systems and equipments operational. The significance of MDS data for management decisions throughout the entire material function makes it imperative that data elements recorded be accurate and that quality data be obtained.

To insure accurate data reporting all of the data are given a comprehensive edit in accordance with criteria outlined in Air Force Technical Order (AFTO) 00-20-2 (ref 41). This edit produces five reports providing information concerning the type of errors in the data submitted and are used at major command and base level to isolate recording inaccuracies for which corrective action is required. Once corrections are made the data are analyzed to identify failures from maintenance actions by identifying specific combinations of maintenance codes (how malfunction, action taken, when discovered, etc.). Maintenance action and the number of maintenance manhours for each maintenance action are also tabulated. Equipment operating time is not reported into MDS; therefore, operating time must be estimated or derived from another source. In the case of this study operating times for all equipments except the E-3A were derived from estimates made by using personnel or Elapsed Time Meter readings (if available) provided by using units on two different surveys. The reported flying time was used as the airborne operating time for the E-3A. An estimate of the ratio of ground operating time to flight hours provided by personnel at Tinker AFB was used to derive the ground operating time for the E3-A.

It should be understood at this point that the depth of information that is contained within the MDS and is retrievable is governed by the level of maintenance authorized to field unit personnel. For example, if an element of a system has been maintenance coded "Depot Repair Only" and is removed in the field for an apparent failure of the item, there is no information available from within the MDS that confirms or denies the failure or cause of failure. Therefore, any system Mean Time Between Failure (MTBF) computed on the basis of assumed, but unconfirmed, item failures reduces confidence in the MTBF calculation. On the other hand, it is frequently found that field maintenance personnel are authorized to repair an item down to and including piece part or component replacement. The MDS does contain piece part replacement and consumption data. Where such data exists, it would appear to be a valid source for confirming item failures and making MTBF calculations. However, a recent study performed by the Institute for Defense Analysis (IDA) (ref 42) found that "non-faulty components are removed in 4 - 43% of all corrective maintenance actions..." and "technicians fail to find a faulty part or damage a good part in about 10% of all maintenance actions. These findings may be due to inadequate test equipment, tools, and maintenance manuals, as well as to inadequate training." In support of the IDA findings, it is interesting to note that in one of the MDS data products it was recorded that from seven bases maintaining AN/TPS-43 radars over a 12-month period, 90 piece parts were replaced in the transceiver C and O unit. Thirty-five piece part replacements, or 39% of the total, occurred at a single base. The remaining six bases averaged nine piece parts replaced during the same time period. Thus, questionable maintenance actions at a single base distorts any composite MTBF calculation.

It would appear that the MDS is not a good source of data for this report. We believe this is not the case. The data we did receive was useful because we were assessing the impact of the power generation or ECU on the system (TSC-60V, TSQ-91, etc.) where both the power generation and ECU equipments and the system were subject to the same maintenance reporting rules and in most cases were reported by the same unit. Therefore, the MDS reliability numerics for one system, which may or may not reflect the system's actual reliability, should be comparable to the MDS reliability numerics for the power generation and ECU equipments. This is particularly true for mature systems. As a result, our major concern was not the inadequacies of the MDS but rather that sufficient ancillary E/M equipment data are reported into the system.

Equipment Status Reports: Another source of Air Force data independent of the MDS is the Equipment Status Report (ESR). ESRs deal with availability of systems to perform the mission. The Production Analysis Summary referred to in the Data Collection section is produced from monthly ESRs. The value of this information is that it is a measure of the impact of the ancillary E/M equipment independent of operating time. The mission capable rate is the percentage of calendar time that the equipment is available to the command for immediate use. The reports are a direct measurement of the ability of the Air Force's support function (maintenance, supply, etc.) to furnish mission capable equipment to the operational units. However, like the MDS, only limited types of equipments are covered by ESRs and of those equipments covered the reporting is only for the equipment status and not for its subsystems. In the final evaluation, ESR data appear to be a good assessment of availability as seen by the equipment users.

Initial Supply Support List (ISSL): The ISSL is a list of parts for a specific equipment which are authorized to be ordered through the base supply system. Examination of the MD-4 and A/E24U-8 ISSLs revealed a low number of parts on each list. Parts not on the list must be individually procured by the unit, often from local vendors. Sacramento ALC confirmed our suspicion of a high rate of local parts procurement on ancillary E/M equipment, and further informed us that no data were available on local parts procurement. Establishing a failure rate from parts replacement was therefore unrealistic.

3.2.2 IITRI E/M Equipment Surveys

Survey One: The first survey was generated to gain elapsed time meter readings (ETM); evaluate the AFTO Form 95, Significant Historical Record, as a data source; and to determine which ancillary E/M equipments were being used with which systems in the field.

ETM readings were received on 11 generators and 4 Environmental Control Units (ECU). Due to the small number of responses, insufficient data were available to derive statistically significant operating time estimates that would be valid for the entire Air Force generator and ECU inventory. ETM readings for the A/E24U-8 are given for each EMU-30 and not for the entire unit. It was also learned that ETM readings on all the equipment surveyed may not be a good estimate of operating time due to unknown replacement times of ETM meters and poor recordkeeping on ETM readings.

It was hoped that access to the AFTO Form 95 would provide good failure information. The AFTO Form 95 remains with the equipment at all times providing a maintenance record unaffected by deployments, returns to depot or base changes. The survey revealed that out of 154 responses only 13 responses said that all equipment failures were recorded on the Form 95. The most common comment was that only TCTO changes and some major repairs were recorded. We concluded from the responses that the quality of the failure reporting on AFTO Form 95 not only varied greatly from unit to unit but also from individual to individual within the units. The result was that the AFTO Form 95 was considered unuseable for failure information.

Equipment usage was also established from the survey. The A/E24U-8 was the most widely used engine generator and the MD-4 was the most widely used power converter. The A/E24U-8 was used with 31 of the 52 C^3I equipments and the MD-4 was used with 24 of 52. The A/E32C-24 and A/E32C-25 air conditioners were the most widely used ECUs. They were each associated with 13 of the 52 C^3I equipments. The AN/TSC-60(V) utilized the greatest variety of electrical power generators and ECUs being identified with 7 different electrical power generators and 3 ECUs. The usage information was used primarly to help select the C^3I equipments to be studied.

The first survey was conducted concurrently with another survey (ref 43). One of the objectives of the other survey was to obtain operational profile data for AF ground tactical equipments. These data were provided by subjective estimates made by using personnel. Data were provided for the AN/TSC-60(V), AN/TSQ-91, AN/TSQ-92 and AN/TSQ-93 systems, and were used to develop operating time estimates for use during this study by the following equation:

Operating hours/year = [(Number of days operating at home station/year) X (Number of hours operated/day)] + [(Number of deployments/year) X (Number of days deployed/deployment) X 24 hours/day)]

The operating hour estimates are provided in the following sections with the detailed analysis of the individual systems.

Survey Two: The second IITRI survey was conducted to gain failure experience data on the power generators, power converters and ECU equipments used with C^3I systems. Field experience data were received on 122 engine generators, 18 motor generators and 202 ECUs. The data from the survey were required because the power equipments were not included in the MDS reports, and only the A/E24U-8 power equipment was included in the ESRs.

The R/M numerics derived from this survey data are presented in the following section with the detailed analysis of the power generation, power conversion and ECU equipments.

The Wilcoxon-Mann-Whitney (W-M-W) Non-parametric Rank Sum Hypothesis Test (ref 44) was run on the sample data for the A/E24U-8 to determine if it was reasonable to assume that the operating time samples from the two surveys came from the same population. A significance level of 0.05 was chosen for the accept-reject criteria. The test showed that there is no reason to believe that the averages of the two groups differ; therefore, it was concluded that the data were from the same population and that the equipment usage during the second survey could be assumed to be the same as the equipment usage during the first survey. The A/E24U-8 was chosen for the test since it was the only equipment that had a statistically significant sample available from both surveys. The results of the test are significant since the R/M of the ancillary equipment which was derived from the second survey data will be compared with the R/M of the system, and the system R/M numerics were calculated using operating time derived from the first survey.

3.3 R/M Analysis

Two distinct methods were utilized to determine the reliability/maintainability (R/M) impact of ancillary electromechanical (E/M) equipments on the C^3I systems which they support.

The first method that was utilized was to compare achieved R/M numerics of the E/M equipments with the specified equipment values to determine if the R/M is different from what was anticipated for the equipments. This method was utilized because it did not limit the number of E/M equipments to those that support the five systems selected for the study. A direct measure of the R/M impact of E/M equipments on C^3I systems can not be ascertained with this method, but it can give an indication that the impact is higher/lower than what was anticipated.

By necessity the analyses were restricted to making comparisons between inherent R/M numerics and field experience data. Since the inherent numerics consider only part failures and optimum repair conditions, and since the field experience data may or may not conform to these restrictions, a definite bias may exist where the achieved R/M numeric is always worse than the specified numeric. A second method of analysis was developed that would cancel out this bias. This second method measured the percent of achieved system failure rate, maintenance time, and maintenance actions associated with the ancillary E/M equipment and compared this percentage with what was called out as a requirement in the procurement specification or what was specified or demonstrated on similar type equipments during Initial Production Tests (IPT) (ref 3-18). The method required that specified and/or predicted R/M numerics be available. C^3I systems for which some specified and/or predicted R/M numerics were available and for which field experience data were available are the AN/TSC-60(V), AN/TSQ-91, AN/TSQ-92 and AN/TSQ-93, and the E-3A. If an R/M numeric was not specified in either the procurement specification or in the IPT reports, the results of the IPT test were used. The use of test results or field experience on similar type equipments is an accepted method for obtaining R/M predictions when other data are not available. The rationale for using the IPT results was that all of the equipments passed the IPT; therefore, the results were the best available prediction for the E/M equipments considered in this study.

It is important to note that a reference such as a specified or predicted numeric is not necessary to assess the impact that ancillary E/M equipments have on the achieved R/M of C^3I systems. They are necessary to assess whether the impact is different from what was anticipated during the conceptual and development phases of the system, and, therefore, whether they have an adverse effect on system R/M. The impact that the ancillary E/M equipments have on the R/M of C^3I systems then was measured as a percentage of the system R/M. The anticipated impact based on specified and/or predicted numerics can be used to judge whether the R/M of the E/M equipments had an adverse effect on C^3I system R/M.

There are many attributes currently utilized to measure the R/M effectiveness of ground tactical electromechanical equipments. The following attributes were chosen to measure the effectiveness of the equipments chosen for this study.

Mean-Time-Between-Failure (MTBF). MTBF is a measure of life-length between unscheduled maintenance due to equipment failures. It is calculated by summing the total time and dividing by the number of failures that occurred during the time span. Two measures of MTBF were calculated. The first was calculated using calendar hours as the time base. Since ground tactical electromechanical equipments spend a large percentage of time (second survey estimate of 81% for ECUs) in the nonoperating state, it is better to use calendar hours than operating hours to measure the number of unscheduled maintenance actions due to failures that can be expected to occur during a given period of possession. The second MTBF calculation utilized operating hours as the time base. Since the equipment is usually operating during a mission, this measure gives an indication of the number of unscheduled maintenance actions due to failures that can be expected to occur during a mission, and, therefore, can be used to calculate a mission reliability. Also since reliability requirements, either reliability or MTBF, are stated as a function of operating time, this method of calculating MTBF must be used to measure the effectiveness of the equipment (during test or in the field) against the requirement.

Mean-Time-Between-Maintenance (MTBM). MTBM is a measure of life-length between unscheduled maintenance due to failures, induced malfunctions and no defect found states. It is calculated by summing the total time and dividing by the number of unscheduled maintenance actions. This measure of life-length gives a more realistic indication of field performance than does MTBF since induced malfunctions and equipment outages that can't be traced to a failed part routinely occur in the field. Two measures of MTBM, one based on calendar hours and one based on operating hours were calculated. The same rationale for utilizing the two measures that was used for MTBF applies for MTBM.

Mean-Time-To-Repair (MTTR). MTTR is a measure of the expected downtime due to unscheduled maintenance actions. MTTR usually includes only the time actually spent to restore the unit to an operating state and does not include time waiting for parts. MTTR is calculated by summing the actual repair times and dividing by the number of repair actions. MTTR is not a good measure of actual field downtime or manhours spent to repair since it does not include wait times nor is it a function of manhours; however, it is a good indication of active maintenance time required and it is used for both reliability and maintenance requirements and must be used to measure the effectiveness of the equipment (during test or in the field) against the requirement.

Mean Downtime (MDT). MDT is a measure of the expected downtime due to unscheduled maintenance actions. This measure includes both actual repair time and time spent waiting for parts. MDT is calculated by summing the total time the equipment is down due to repair and dividing by the number of unscheduled maintenance actions. MDT is a better measure of equipment outage than MTTR and, therefore, gives a better measure of long-term equipment availability.

Reliability (R). Reliability is a measure of the probability that the equipment will function successfully for a given period of time and given specified operating conditions. In other words it is a measure of the probability of mission success. It is a function of time and failure rate and is calculated by the following equation:

$$R(t) = e^{-\int \lambda dt}$$

where e - is the symbol for the base of the napierian logarithm,

t - is the mission length, and
λ - is the failure rate

Reliability is the numeric that is specified in many procurements and could be used to measure the effectiveness of the equipment (during test or the field) against the requirement. If, however, the failure rate is constant or assumed to be constant the reliability equation simplifies to:

$$R(t) = e^{-t/m}$$

where m - is the MTBF

Therefore MTBF can be used as a measure of reliability.

The constant failure rate assumption has been used for the electromechanical equipments considered in this study and it will be used to quantify the achieved reliability for comparison purposes.

Availability (A). Availability is a measure of the probability that the equipment will be available to perform its mission at any instant in time. It is specified in many procurements as a measure of maintenance. The method for calculating availability called out in ground tactical electromechanical equipment procurements is:

$$A_a = M/(M + R)$$

where A_a is the achieved availability, M is a measure of equipment uptime and R is a measure of equipment downtime. The attributes used to measure uptime and downtime vary from procurement to procurement. A second measure of availability that is not called out in procurements but for which data are recorded on some demonstration tests is the ratio of successful starts to attempts to start. These data were recorded on the second survey and are used as an alternate measure of availability.

A survey was initiated to gather data which could be used to develop estimates of operating times for the ancillary E/M equipments. This survey was conducted jointly with another IITRI project. These data were deemed necessary since Air Force Maintenance Data System (MDS) field experience data were to be used to provide the R/M estimates and since the MDS does not report operating times. The survey form requested that personnel at selected Air Force units record operating time meter readings and the date of the reading for two points in time - when the unit was received at the Air Force base and the date the survey was completed. The data received were used to develop an average operate time/calendar year (ot/cy) for each equipment. A mean ot/cy for each equipment type was generated from these data. Since the survey was initiated prior to the final selection of equipments for the study, the survey results contain ot/cy's for additional E/M equipments. The mean and median ot/cy is given by equipment type in Table 3.3-1.

A second survey was instituted which provided a second estimate of ot/cy. This survey was sent to selected Air Force units with the request that they record operating time meter readings and the date of the reading for two points in time - start of the survey and end of the survey. The survey period was to run approximately ninety days. The respondents were requested to estimate the actual operating hours accrued during this period for those equipments that do not have operating time meters. A list of the units surveyed is given in Table 2.2.2-1. The mean ot/cy is given by equipment type in Table 3.3.1-2 and 3.3.1-5.

The operating time estimates obtained from a survey conducted during a previous IITRI study (ref 43) were used to obtain an estimate of operating time for the AN/TSC-60, AN/TSQ-91, AN/TSQ-92 and AN/TSQ-93 C^3I systems. These estimates of operating time/calendar year (ot/cy) are based on subjective estimates made by using personnel at selected Air Force (AF) and Air National Guard (ANG) units. The analyses of the data are presented along with the analyses of the systems in the following sections.

3.3.1 Ground Tactical Ancillary E/M Equipment Analyses

This section presents the analyses of the achieved R/M of ancillary E/M equipments against the specified and/or predicted R/M for the equipment. The purpose of the analyses was to obtain an estimate of the impact the ancillary E/M equipment might have on the C^3I system they are supporting. For the purposes of

TABLE 3.3-1: SURVEY ONE E/M EQUIPMENT OPERATE TIME

EQUIPMENT	NO. OF READINGS	OPERATE TIME MEAN HR/YR	OPERATE TIME MEDIAN HR/YR
A/E24U-8	26	240.8	100.5
MB-15	15	136	81
MB-18	23	154.2	121
EMU-12E	2	101	101
EMU-19	28	110	122.5
EMU-21	10	103.2	106.1
MEP-006A	11	170.5	155
MEP-016	4	28.3	16.7
MEP-026	2	184.6	184.6
MD-2	6	477.7	554.6
MD-4	14	1487.5	751.2
H-1 Heater	2	9.6	9.6
AE32C-18	1	1468.4	1468.4
AE32C-24	2	965.3	965.3
AE32C-26	1	982.3	982.3

this study an adverse impact is defined as an R/M numeric that did not satisfy the specified R/M numeric or was worse than the value generated during the Initial Production Tests (IPT). Selected achieved R/M numerics were analyzed from data acquired during the second survey and were compared with the specified R/M numerics for the equipments.

Data were also extracted from Initial Production Tests conducted by the U.S. Army at the Aberdeen Proving Ground (ref 2 to 18). These data were used as an estimate of the predicted R/M for the equipments being studied since many of E/M equipments only have one specified R/M numeric, and, since all of the equipments tested passed the R/M requirements of the Initial Production Tests it was felt that these data would be a good bench mark for comparison of the actual achieved data. One problem with the Initial Production Test (IPT) data was that the equipments are not identical to the E/M equipments surveyed in the field. To resolve this problem, an average of the IPT data was used as the reference for comparison. Table 3.3.1-1 contains the IPT data for ECUs and Table 3.3.1-4 contains the IPT data for the power equipment. Table 3.3.1-2 contains a summary of the data collected on ECUs during the second survey. Table 3.3.1-5 contains a summary of the data collected on the power equipment during the second survey. Table 3.3.1-7 contains a summary of data collected for the power distribution equipment that was derived from the TAC BLIS and D056B5503 reports. The specified MTBF and Endurance for the ECU equipment was obtained from MIL-A-38339D (ref 45). The specified R/M numerics for the power equipment was obtained from MIL-G-83380, MIL-M-4820E, MIL-M-4818D, MIL-G-26727D and MIL-G-52884 (ref 46 to 50). The comparsion data are shown in Table 3.3.1-3 for ECU equipments, Table 3.3.1-6 for power equipments and Table 3.3.1-8 for the power distribution equipment.

The allocated R/M numerics for the AN/TSQ power distribution networks were extracted from the AAA report (ref 32). The R/M numerics given for the power distribution networks in the reference were for the console, data processing, ancillary equipment and group display modules. No R/M numerics were given for the air conditioning, furnishings, operations or comm center module power distribution networks nor were there a provision for them in the reliability math model. The allocated R/M numerics given in Table 3.3.1-8 are based on the

TABLE 3.3.1-1: INITIAL PRODUCTION TEST R/M DATA FOR ECU EQUIPMENT

ATTRIBUTE	REFERENCE NUMBER											TOTALS
	8	10	5	7	3	4	2	6	14	15	16	
NUMBER OF EQUIPMENTS	3	12	2	5	3	3	2	3	3	3	3	42
MEAN TIME BETWEEN FAILURES (HOURS)												
(POSSESSION HOURS, CHARGEABLE FAILURES)												
POINT ESTIMATE	6804	65088	728	26260	-	-	-	-	16416	-	-	10938
LOWER 90% CONFIDENCE INTERVAL LIMIT	2162	13717	491	5538	5746	9255	5866	8775	6350	1274	4520	7832
UPPER 90% CONFIDENCE INTERVAL LIMIT	38278	12.7×10^6	1126	512281	-	-	-	-	60058	-	-	15734
MEAN TIME BETWEEN FAILURES (HOURS)												
(OPERATING HOURS, CHARGEABLE FAILURES)												
POINT ESTIMATE	2262	7285	536	1926	-	-	-	-	1335	-	-	1452
LOWER 90% CONFIDENCE INTERVAL LIMIT	719	1535	362	406	612	326	509	739	516	344	344	1040
UPPER 90% CONFIDENCE INTERVAL LIMIT	12728	142008	829	37548	-	-	-	-	4883	-	-	2089
SINGLE SIDED 90% CONFIDENCE LIMIT	850	1873	390	495	796	424	661	960	599	447	579	1110
CHARGEABLE FAILURES	2	1	18	1	0	0	0	0	3	0	0	25
NON-CHARGEABLE FAILURES	4	3	-	2	2	0	2	1	1	-	1	16
SCHEDULED MAINTENANCE (CLOCK-HOURS/MAN-HOURS)	101.4/ 100.1	14.5	-	3.2	13.2	0	0.2	0	-	-	0	132.5/ 131.2
UNSCHEDULED MAINTENANCE (CLOCK-HOURS/MAN-HOURS)	7.5/ 9.2	0	-	6.3/ 9.3	4.2	0	2.75	41.2	-	-	0	62.0/ 66.6
MAINTENANCE ACTIONS	103	4	18	19	20	0	3	117	4	-	1	289
UNSCHEDULED MAINTENANCE ACTIONS	12	4	18	4	2	0	2	1	4	0	1	48
MEAN TIME TO REPAIR (CLOCK-HOURS)	0.62	3.62	-	1.58	2.10	0	1.38	-	-	-	0	2.48
MAINTENANCE RATIO (CLOCK-HOURS, OPERATING HOURS)	0.0241	0.0020	-	0.0049	-	0	-	-	-	-	0	0.0054
POSSESSION HOURS	13608	65088	13104	26280	17208	27720	17568	26280	49248	3816	13536	273456
OPERATING HOURS	4525	7285	9651	1926	1834	978	1524	2214	4004	1030	1334	36305
AVAILABILITY												
A_a (OPERATING HOURS)	0.9997	0.9995	-	0.9992	-	-	-	-	-	-	-	0.9983
A_s	-	-	-	-	-	-	1.0000	-	-	-	-	1.0000
NUMBER OF STARTUPS	-	-	-	-	-	-	111	-	-	-	-	111
FAILURES TO START	-	-	-	-	-	-	0	-	-	-	-	0
STOPPAGE FAILURES	-	-	-	-	-	-	2	-	-		-	2
TOTAL MAINTENANCE DOWNTIME (HOURS)	-	-	-	-	-	-	-	-	-	1.5	-	1.5
REQUIREMENTS												
RELIABILITY AT 90% CONFIDENCE LIMIT (t = 24 HOURS)	0.95	0.95	-	0.95	0.95	-	-	0.95	-	-	-	-
AVAILABILITY	0.95	0.95	-	0.95	0.95	-	-	0.95	-	0.95	-	-
ENDURANCE TIME (HOURS)	1500	-	-	-	-	300	500	-	-	-	-	-
MTBF (SPECIFIED) (HOURS)	-	-	-	-	-	-	-	-	960	960	960	-
MAINTENANCE RATIO	-	-	-	-	-	-	-	-	-	-	≤ 0.03	-
SCHEDULED MAINTENANCE INTERVAL (HOURS)	-	-	-	-	-	-	-	-	-	-	≥250	-

NOTES:

1) *IF ONLY ONE ESTIMATE IS GIVEN, CLOCK-HOURS = MANHOURS.*

TABLE 3.3.1-2: SECOND SURVEY R/M DATA FOR ECU EQUIPMENT

ATTRIBUTE	A/E 32C- 24	25	27	23	26	39	18	17	EJU-100	TOTALS
NUMBER OF AF UNITS	6	6	6	1	3	1	3	1	1	11
NUMBER OF ECU'S	84	40	51	2	14	1	8	1	1	202
MEAN TIME BETWEEN FAILURE (HOURS)										
(FOR POSSESSION HOURS)										
POINT ESTIMATE	6317	24750	25161	4992	5960	-	3878	-	-	9292
LOWER 90% CONFIDENCE INTERVAL LIMIT	4724	10814	11965	1052	3020	793	1844	1146	833	7405
UPPER 90% " " "	8632	72527	63866	97310	13675	-	9844	-	-	11806
MEAN TIME BETWEEN FAILURE (HOURS)										
(FOR OPERATING HOURS)										
POINT ESTIMATE	1547	3285	3163	560	1681	-	713	-	-	1757
LOWER 90% CONFIDENCE INTERVAL LIMIT	1157	1435	1504	118	852	187	339	-	34	1400
UPPER 90% " " "	2114	9626	8028	10916	3857	-	1809	-	-	2232
SINGLE SIDED 90% CONFIDENCE LIMIT	1226	1641	1704	144	957	243	385	-	44	1474
NUMBER OF FAILURES DURING										
STARTUP	2	0	1	0	1	0	1	0	0	5
OPERATION	35	6	8	2	7	0	4	1	0	63
MEAN TIME TO REPAIR (CLOCK-HOURS)	3.77	1.50	8.14	4.00	5.90	0	2.0	2.00	0	4.47
MEAN WAIT TIME (CLOCK-HOURS)	>197	>1338	>1860	>1356	>949	0	>426	2	0	>725
MEAN DOWN TIME (CLOCK-HOURS)	>201	>1340	>1868	>1360	>955	0	>428	4	0	>730
NUMBER OF TIMES ELECTRONIC EQUIPMENT										
SHUT-OFF	1	0	0	0	1	0	0	-	0	2
CONTINUED OPERATION DURING BECAUSE OF FAILURE	18	5	8	2	5	0	4	-	0	42
AVERAGE SWITCHOVER TIME (HOURS)	1.83	0.43	-	0.5	4.0	-	0.67	-	-	1.29
AVERAGE POSSESSION HOURS	2482	2475	2467	2496	2554	2376	2424	3432	2496	2484
AVERAGE OPERATE HOURS	608	328	310	280	720	560	446	-	102	472
NUMBER OF FAILURES	33	4	5	1	6	0	5	0	0	54
ESTIMATED NUMBER OF STARTUPS	5373	1492	1871	70	840	70	444	1	12	10173
AVAILABILITY										
A_s	0.9996	1.0000	0.9995	1.000	0.9988	1.000	0.9977	1.000	1.000	0.9995
A_a	0.9975	0.9995	0.9974	0.9929	0.9965	-	0.9972	-	-	0.9974
REQUIREMENTS:										
MTBF (HOURS) MINIMUM SPECIFIED AT 90% CONFIDENCE	434	434	434	434	434	434	434	434	-	
ENDURANCE (HOURS)	1000	1000	1000	1000	1000	1000	1000	1000	-	

TABLE 3.3.1-3: COMPARISON STANDARD FOR ECU EQUIPMENTS

ATTRIBUTE	IPT		MIL-A-38339D	A/E 32C-								
	AVERAGE	REQUIREMENT	REQUIREMENT	17	18	23	24	25	26	27	39	TOTALS
MEAN TIME BETWEEN FAILURES (HOURS)												
(OPERATING TIME, CHARGEABLE FAILURES)												
POINT ESTIMATE	1452	960										
LOWER 90% CONFIDENCE INTERVAL LIMIT	1040											
UPPER 90% CONFIDENCE INTERVAL LIMIT	2089											
SINGLE SIDED 90% LIMIT	1110		434									
MEAN TIME BETWEEN MAINTENANCE (HOURS)												
(OPERATING TIME, ALL REPAIRS)												
POINT ESTIMATE	885			-	713	560	1547	3285	1681	3163	-	1757
LOWER 90% CONFIDENCE INTERVAL LIMIT	682			-	339	118	1157	1435	852	1504	793	1400
UPPER 90% CONFIDENCE INTERVAL LIMIT	1169			-	1809	10916	2114	9626	3857	8028	-	2232
SINGLE SIDED 90% LIMIT	719			-	385	144	1226	1641	957	1704	243	1474
MEAN TIME BETWEEN MAINTENANCE (HOURS)												
(POSSESSION HOURS, ALL REPAIRS)												
POINT ESTIMATE	6670			-	3878	4992	6317	24750	5960	25161	-	9292
LOWER 90% CONFIDENCE INTERVAL LIMIT	5141			1146	1844	1052	4724	10814	3020	11965	793	7405
UPPER 90% CONFIDENCE INTERVAL LIMIT	8803			-	9844	97310	8632	72527	13675	63866	-	11806
MEAN SCHEDULED MAINTENANCE (CLOCK-HOURS)	0.5											
MEAN TIME TO REPAIR (CLOCK-HOURS)	2.5			2.0	2.0	4.0	3.8	1.5	5.9	8.1	0	4.5
MEAN DOWN TIME (CLOCK-HOURS)	-			4	>428	>1360	>201	>1340	>955	>1868	-	>730
MAINTENANCE RATIO	0.005	0.030		-	0.3918	0.0107	0.0060	0.0040	0.0071	0.0062	0	0.0061
AVAILABILITY												
A_a (OPERATE TIME)	0.9983	0.95		-	0.9972	0.9929	0.9975	0.9995	0.9965	0.9974	-	0.9974
A_s (START UP/OPERATION FAILURES)	1.0000			1.0000	0.9977	1.0000	0.9996	1.0000	0.9988	0.9995	1.0000	0.9995
RELIABILITY AT 90% CONFIDENCE (t = 24 HOURS)												
(OPERATE TIME, CHARGEABLE FAILURES)	0.9786	0.95		-	0.9396	0.8465	0.9846	0.9927	0.9858	0.9924	0.9060	0.9864
AVERAGE SWITCHOVER TIME (HOURS)	-			-	0.67	0.50	1.83	0.43	4.00	-	-	1.29
PERCENT OF FAILURES WHERE ELECTRICAL EQUIPMENT HAD TO BE SHUTOFF BECAUSE OF FAILURE	-			-	0	0	5	0	17	0	0	4

TABLE 3.3.1-4: INITIAL PRODUCTION TEST R/M DATA FOR POWER EQUIPMENT

ATTRIBUTE	REFERENCE NUMBER 11	9	1	12	13	TOTALS
NUMBER OF EQUIPMENTS	5	2	3	4	3	17
MEAN TIME BETWEEN FAILURES (HOURS)						
(POSSESSION HOURS, CHARGEABLE FAILURES)						
POINTS ESTIMATE	10080	6240	2664	5760	10152	6135
LOWER 90% CONFIDENCE INTERNAL LIMIT	2124	1315	846	2228	2140	3400
UPPER 90% CONFIDENCE INTERNAL LIMIT	196491	121637	14987	21073	197895	12332
MEAN TIME BETWEEN FAILURES (HOURS)						
(OPERATING HOURS, CHARGEABLE FAILURES)						
POINT ESTIMATE	1938	1010	1500	667	1821	1221
LOWER 90% CONFIDENCE INTERNAL LIMIT	408	213	476	258	384	677
UPPER 90% CONFIDENCE INTERNAL LIMIT	37788	19688	8439	2439	35497	2454
SINGLE-SIDED 90% CONFIDENCE LIMIT						752
NUMBER OF STARTUPS	245	134	-	-	-	379
FAILURES TO START	2	0	-	-	-	2
STOPPAGE FAILURES	1	0	-	-	-	1
CHARGEABLE FAILURES	1	1	2	3	1	8
NONCHARGEABLE FAILURES	4	3	6	21	2	36
SCHEDULED MAINTENANCE (CLOCK/MAN HOURS)	11.5	26.7	-	21.4/30.4	25.0	84.6/93.6
UNSCHEDULED MAINTENANCE (CLOCK/MAN HOURS)	4.6	31.6/44.8	-	8.9/10.9	3.9	49/64.2
MAINTENANCE ACTIONS	45	143	-	46	35	269
UNSCHEDULED MAINTENANCE ACTION	10	7	-	16	3	36
MEAN TIME TO REPAIR (CLOCK HOURS)	1.15	4.51	-	0.56	1.30	1.36
MAINTENANCE RATIO (CLOCK-HOURS, OPERATING HOURS)	0.0083	0.0577	-	0.0152	0.0159	0.0137
POSSESSION HOURS	10080	6240	5328	17280	10152	49080
OPERATING HOURS	1938	1010	3000	2000	1821	9769
AVAILABILITY						
A_s	0.9918	1.0000	-	-	-	0.9947
A_a (OPERATING HOURS)	0.9994	0.9956	-	0.9992	0.9993	0.9989
TOTAL DOWN TIME (CLOCK-HOURS)	-	417	-	-	-	417
REQUIREMENTS						
RELIABILITY AT 90% CONFIDENCE (t=24 HOURS)	0.95	0.90	-	-	0.95	-
AVAILABILITY	0.85	0.95	-	-	0.85	-
ENDURANCE TIME (HOURS)	500	500	1000	500*	500	-
MTBF (SPECIFIED) (HOURS)	-	-	450	500	-	-

* REDUCED FROM 5000 HOURS

TABLE 3.3.1-5: SECOND SURVEY R/M DATA FOR POWER EQUIPMENT

ATTRIBUTE	A/E 24U-81	MD-4	MD-2	MB-15	MEP005	MEP006	TOTALS
NUMBER OF AF UNITS	6	5	2	5	1	1	12
NUMBER OF GENERATORS	67	16	2	23	25	7	140
MEAN TIME BETWEEN MAINTENANCE (HOURS)							
(FOR POSSESSED HOURS)							
POINT ESTIMATE	2145 (1)	3051	-	3094	9920	7848	2963
LOWER 90% CONFIDENCE INTERVAL LIMIT	1767 (1)	1952	801	2129	5027	2493	2539
UPPER 90% CONFIDENCE INTERVAL LIMIT	2626 (1)	5050	-	4668	22761	44152	3476
MEAN TIME BETWEEN MAINTENANCE (HOURS)							
(FOR OPERATING HOURS)							
POINT ESTIMATE	167 (1)	1745	-	35.5	308	154	348
LOWER 90% CONFIDENCE INTERVAL LIMIT	138 (1)	1116	197	24.4	156	48.8	295
UPPER 90% CONFIDENCE INTERVAL LIMIT	205 (1)	2888	-	53.5	707	864	404
SINGLE-SIDED 90% LIMIT	144 (1)	1214	256	26.2	176	57.8	308
NUMBER OF STARTUPS	4201	36	112	599	354	93	5395
NUMBER OF FAILURES DURING							
STARTUP	27	1	0	12	1	0	41
OPERATION	47	14	0	8	5	2	76
MEAN TIME TO REPAIR (CLOCK-HOURS)	6.28 (1)	44.7	-	4.19	4.00	3.00	9.68
MEAN WAIT TIME (CLOCK-HOURS)	>207 (1)	>828	-	277	>981	>888	>366
MEAN DOWN TIME (CLOCK-HOURS)	>213 (1)	>873	-	>281	>985	>891	>376
AVERAGE SWITCHOVER TIME (HOURS)	0.10 (1)	0.68	-	0.15	0.05	-	0.25
AVERAGE POSSESSION HOURS	2370 (1)	2670	2556	2690	2381	2242	2455
AVERAGE OPERATE HOURS	92.5 (1)	1527	292	30.8	74.0	43.9	199/288 (2)
NUMBER OF FAILURES	74	14	0	20	6	2	116
AVAILABILITY = 1-(No. of STARTUP FAILURES/NUMBER OF STARTUPS)	0.9936	0.9722	1.0000	0.9800	0.9972	1.0000	0.9924

NOTES:

1) FOR EACH EMU-30
2) 134 EMU's/67 - 8's

TABLE 3.3.1-6 COMPARISON STANDARD FOR POWER EQUIPMENTS

ATTRIBUTE	REQUIREMENTS MIL-G-83380 A/E 24U-8	MIL-M-48206 MB-4	MIL-M-48180 MD-2	MIL-G-26727D MB-15	MIL-G-52884/5A MEP005A	MIL-G-52884/8A MEP006A	IPT (1)	ACHIEVED R/M IPT	A/E 24U-8	MB-4	MD-2	MB-15	MEP005	MEP006	TOTALS
MEAN TIME BETWEEN FAILURES (HOURS)															
(OPERATING TIME, CHARGEABLE)															
POINT ESTIMATE*		4000	4000	1000			450/500	1221							
LOWER 90% CONFIDENCE INTERVAL LIMIT								677							
UPPER 90% CONFIDENCE INTERVAL LIMIT								2054							
MINIMUM ACCEPTABLE	500	1000	1000		335	250		752							
SINGLE-SIDED 90% CONFIDENCE LIMIT															
MEAN TIME BETWEEN MAINTENANCE (HOURS)															
(OPERATING TIME, ALL REPAIRS)															
POINT ESTIMATE		400	400					222	167	1745	-	35.5	308	154	345
LOWER 90% CONFIDENCE INTERVAL LIMIT								182	138	1116	97.5	24.4	156	48.8	295
UPPER 90% CONFIDENCE LIMIT								290	205	2888	-	53.5	707	864	404
SINGLE-SIDED 90% CONFIDENCE LIMIT								173	144	1714	256	26.2	176	52.8	308
MEAN TIME BETWEEN MAINTENANCE (HOURS)															
(POSSESSION HOURS, ALL REPAIRS)															
POINT ESTIMATE								6135	2145	3051	-	3094	9920	7846	2963
LOWER 90% CONFIDENCE INTERVAL LIMIT								3400	1763	1952	803	2129	5027	2493	2539
UPPER 90% CONFIDENCE INTERVAL LIMIT								12332	2626	5050	-	4668	22761	44152	3476
MEAN SCHEDULED MAINTENANCE (CLOCK HOURS)								0.4							
MEAN TIME TO REPAIR (CLOCK HOURS)		0.5	0.5	0.5				1.4	6.3	44.7	-	4.2	4.0	2.[illegible]	[illegible]
MEAN DOWN TIME (CLOCK HOURS)									<213	873	-	<283	<985	<891	<776
MEAN MAN HOURS TO REPAIR (HOURS)		1.0	1.0					1.8	-	-	-	-	-	-	-
MAINTENANCE RATIO								0.011[illegible]	0.0837	0.0363	0.0	0.1270	0.022[illegible]	0.0287	0.0500
AVAILABILITY															
A_o (OPERATE TIME) (2)							0.85/0.95	0.9989	0.9636	0.9750	-	0.8982	0.9872	0.9809	0.9726
A_s (STARTUP/NUMBER OF ATTEMPTED STARTUPS)								0.9947	0.9936	0.9727	1.0000	0.9800	0.9912	1.0000	0.9874
RELIABILITY AT 90% CONFIDENT (1-20 HOURS) (2)							0.95/0.90	0.9606	0.8465	0.9904	0.9104	0.4001	0.8725	0.6607	0.9252
AVERAGE SWITCHOVER TIME (HOURS)									0.10	0.65		0.15	0.05		0.25

NOTES 1) DIFFERENT REQUIREMENTS WERE SPECIFIED FOR THE IPT EQUIPMENTS
2) TWO DIFFERENT REQUIREMENTS

TABLE 3.3.1-7: ACHIEVED R/M DATA FOR POWER DISTRIBUTION EQUIPMENT

ATTRIBUTE	TSC-60(V)-1 TAC BLIS	TSC-60(V)-1 D056B5503	TSC-60(V)-2 D056B5503	TSC-60(V)-3 D056B5503	TOTAL TSC-60(V)
NUMBER OF EQUIPMENTS	12	58	57	15	130
MEAN TIME BETWEEN MAINTENANCE EVENTS					
(FOR POSSESSED HOURS)					
POINT ESTIMATE	105120	127020	49191	18771	54229
LOWER 90% CONFIDENCE INTERVAL LIMIT	22154	55498	29441	9992	37659
UPPER 90% CONFIDENCE INTERVAL LIMIT	2049123	372220	92040	40000	80938
SINGLE SIDED 60% CONFIDENCE LIMIT					
MEAN TIME BETWEEN MAINTENANCE EVENTS					
(FOR OPERATE HOURS)					
POINT ESTIMATE	36739	38640	15189	5709	16496
LOWER 90% CONFIDENCE INTERVAL LIMIT	7743	16882	8956	3039	11456
UPPER 90% CONFIDENCE INTERVAL LIMIT	716164	113229	27999	12164	24621
SINGLE SIDED 60% CONFIDENCE LIMIT					
MEAN TIME BETWEEN SYSTEM DOWNTIME					
(FOR OPERATE HOURS)					
POINT ESTIMATE					
LOWER 90% CONFIDENCE INTERVAL LIMIT					
UPPER 90% CONFIDENCE INTERVAL LIMIT					
SINGLE-SIDED 60% CONFIDENCE LIMIT	39847				
MEAN TIME TO REPAIR (HOURS)	0.5	4.2	1.8	4.8	3.2
AVERAGE POSSESSION HOURS	8760	8760	8760	8760	8760
AVERAGE OPERATE HOURS	3061.6	2664.8	2664.8	2664.8	2664.8
NUMBER OF MAINTENANCE EVENTS	1	4	10	7	21
NUMBER OF SYSTEM OUTAGES	0				

TABLE 3.3.1-7: ACHIEVED R/M DATA FOR POWER DISTRIBUTION EQUIPMENT (CONT'D)

ATTRIBUTE	TSQ-91		TSQ-92	TSQ-93	TOTAL
	TAC BLIS	D056B5503	D056B5503	D056B5503	TSQ
NUMBER OF EQUIPMENTS	5	16	6	13	35
MEAN TIME BETWEEN MAINTENANCE EVENTS (FOR POSSESSED HOURS)					
POINT ESTIMATE	8760	2748		28470	5574
LOWER 90% CONFIDENCE INTERVAL LIMIT	4165	2176		12439	4453
UPPER 90% CONFIDENCE INTERVAL LIMIT	22234	3517		83428	7065
SINGLE SIDED 60% CONFIDENCE LIMIT			57006		
MEAN TIME BETWEEN MAINTENANCE EVENTS (FOR OPERATE HOURS)					
POINT ESTIMATE	4080	1280		9798	2170
LOWER 90% CONFIDENCE INTERVAL LIMIT	1940	1014		4281	1734
UPPER 90% CONFIDENCE INTERVAL LIMIT	10355	1638		28711	2750
SINGLE SIDED 60% CONFIDENCE LIMIT			8785		
MEAN TIME BETWEEN SYSTEM DOWNTIME (FOR OPERATE HOURS)					
POINT ESTIMATE					
LOWER 90% CONFIDENCE INTERVAL LIMIT					
UPPER 90% CONFIDENCE INTERVAL LIMIT					
SINGLE-SIDED 60% CONFIDENCE LIMIT	22126				
MEAN TIME TO REPAIR (HOURS)	3.5	4.6	0	5.2	4.6
AVERAGE POSSESSION HOURS	8760	8760	8760	8760	8760
AVERAGE OPERATE HOURS	4080	4504.3	1350	3014.7	3410.3
NUMBER OF MAINTENANCE EVENTS	5	51	0	4	55
NUMBER OF SYSTEM OUTAGES	0				

TABLE 3.3.1-7: ACHIEVED R/M DATA FOR POWER DISTRIBUTION EQUIPMENT (CONT'D)

ATTRIBUTE	TOTAL GROUND D056B5503	TOTAL GROUND TAC BLTS
NUMBER OF EQUIPMENTS	165	17
MEAN TIME BETWEEN MAINTENANCE EVENTS		
(FOR POSSESSED HOURS)		
POINT ESTIMATE	19018	24820
LOWER 90% CONFIDENCE INTERVAL LIMIT	15714	12578
UPPER 90% CONFIDENCE INTERVAL LIMIT	23219	56948
SINGLE SIDED 60% CONFIDENCE LIMIT		
MEAN TIME BETWEEN MAINTENANCE EVENTS		
(FOR OPERATE HOURS)		
POINT ESTIMATE	6129	9523
LOWER 90% CONFIDENCE INTERVAL LIMIT	5064	4826
UPPER 90% CONFIDENCE INTERVAL LIMIT	7482	21850
SINGLE SIDED 60% CONFIDENCE LIMIT		
MEAN TIME BETWEEN SYSTEM DOWNTIME		
(FOR OPERATE HOURS)		
POINT ESTIMATE		
LOWER 90% CONFIDENCE INTERVAL LIMIT		
UPPER 90% CONFIDENCE INTERVAL LIMIT		
SINGLE-SIDED 60% CONFIDENCE LIMIT		61972
MEAN TIME TO REPAIR (HOURS)	4.3	3.0
AVERAGE POSSESSION HOURS	8760	8760
AVERAGE OPERATE HOURS	2822.9	3361.1
NUMBER OF MAINTENANCE EVENTS	76	6
NUMBER OF SYSTEM OUTAGES		0

TABLE 3.3.1-8: COMPARISON STANDARD FOR POWER DISTRIBUTION

ATTRIBUTE	AN/TSC-60(V)-1 ALLOCATED	AN/TSC-60(V)-1 ACHIEVED	AN/TSC-60(V)-2 ALLOCATED	AN/TSC-60(V)-2 ACHIEVED	AN/TSC-60(V)-3 ALLOCATED	AN/TSC-60(V)-3 ACHIEVED
MEAN TIME BETWEEN MAINTENANCE (HOURS) (OPERATE HOURS)						
POINT ESTIMATE	73500	38640(3)	61616	15189	45327	5709
LOWER 90% CONFIDENCE INTERVAL LIMIT		16882(3)		8956		3039
UPPER 90% CONFIDENCE INTERVAL LIMIT		113229(3)		27999		12164
SINGLE-SIDED 60% CONFIDENCE LIMIT						
MEAN TIME TO REPAIR (HOURS)	0.2(1)	4.2(3)	0.2(1)	1.8(3)	0.2(1)	4.8
MCT (HOURS)						
POINT ESTIMATE						
MAXIMUM ACCEPTABLE						
AVAILABILITY (AN) (2)	0.99999	0.99989	0.99999	0.99988	0.99999	0.99916
MEAN TIME BETWEEN MAINTENANCE (HOURS) (POSSESSED HOURS)						
POINT ESTIMATE						
LOW						

TABLE 3.3.1-8: COMPARISON STANDARD FOR POWER DISTRIBUTION (CONT'D)

ATTRIBUTE	AN/TSQ-91		AN/TSQ-92		AN/TSQ-93	
	ALLOCATED	ACHIEVED	ALLOCATED	ACHIEVED	ALLOCATED	ACHIEVED
MEAN TIME BETWEEN MAINTENANCE (HOURS)						
(OPERATE HOURS)						
POINT ESTIMATE	6195(4)	1280(3)	85000(5)			9798
LOWER 90% CONFIDENCE INTERVAL LIMIT		1014(3)				4281
UPPER 90% CONFIDENCE INTERVAL LIMIT		1638(3)				28711
SINGLE-SIDED 60% CONFIDENCE LIMIT				8785		
MEAN TIME TO REPAIR (HOURS)						
MCT (HOURS)						
POINT ESTIMATE	1.47	4.6	1.47	0		5.2
MAXIMUM ACCEPTABLE						
AVAILABILITY (AN) (2)	0.99976	0.99676	0.99998	1.0000		0.99947
MEAN TIME BETWEEN MAINTENANCE (HOURS)						
(POSSESSED HOURS)						
POINT ESTIMATE						
LOW						

NOTES:

1) PREDICTED VALUE
2) CALCULATED FROM MTBF AND M ALLOCATIONS
3) D056B5503 REPORT
4) BASED ON MAXIMUM CONFIGURATION SYSTEM
5) BASED ON TWO GROUP DISPLAY MODULES

assumption that the AN/TSQ systems are maximum configuration. This assumption is based on conversations with the Item Manager who indicated that the AN/TSQ inventory used for this study is for maximum configuration systems. The module quantity used to derive the allocated power distribution R/M numeric for the systems are:

Module	System AN/TSQ-91	AN/TSQ-92	AN/TSQ-93
Console	3	--	--
Data Processing	1	--	--
Ancillary Equipment	1	--	--
Group Display	3	2	--

As can be seen no allocated R/M numerics were given for the AN/TSQ-93 Power Distribution Network (PDN) and only one AN/TSQ-92 module type had an allocated R/M numeric for the PDN. No comparisons could be made for the AN/TSQ-93. The achieved results presented for the AN/TSQ-92 will be pessimistic since the allocated system numeric is optimistic. The Work Unit Codes (WUC) that were used to derive the achieved R/M numerics are:

AN/TSQ-91

WUC	MODULE	DESCRIPTION
ABAA0	AN/TSA-34 COMM CENTRAL ELECTRONIC EQUIPMENT SHELTER 1570650-100	POWER ENTRY BOX 1582268-1
ABAB0	AN/TSA-34 COMM CENTRAL ELECTRONIC EQUIPMENT SHELTER 1570650-100	POWER CONTROL PANEL 1570802-100
ABAC0	AN/TSA-34 COMM CENTRAL ELECTRONIC EQUIPMENT SHELTER 1570650-100	INTERNAL CABLING
ACAG0	OA-8446 OPERATIONS CENTRAL OJ-108 OPERATIONS CENTRAL CONSOLE	PANEL, POWER DISTR
ACDC0	ELEC EQUIP SHELTER	CABLESET, CONSOLE MODULE
ADAF0	OA-8447 OPERATIONS CENTRAL GROUP OJ-108 OPERATIONS CENTRAL CONSOLE	POWER DISTR PANEL

ADEAO	ELECTRONIC EQUIPMENT SHELTER	INTERCONNECTING BOX 1582785-100
ADEBO	ELECTRONIC EQUIPMENT SHELTER	INTERCONNECTING BOX 1582786-100
ADEDO	ELECTRONIC EQUIPMENT SHELTER	INTERNAL CABLING
ADEEO	ELECTRONIC EQUIPMENT SHELTER	POWER CONTROL ASSY
AERBO	ELECTRONIC EQUIPMENT SHELTER	POWER CONTROL ASSY
AERAO	ELECTRONIC EQUIPMENT SHELTER	INTERNAL CABLING

AN/TSQ-92

WUC	MODULE	DESCRIPTION
ABAAD	AN/TSA-34 COMM CENTRAL ELECTRONIC EQUIPMENT	POWER ENTRY BOX
ABABO	AN/TSA-34 COMM CENTRAL ELECTRONIC EQUIPMENT	POWER CONTROL PANEL

AN/TSQ-93

WUC	MODULE	DESCRIPTION
AAAAO	OA-8451 COMMUNICATIONS GROUP ELECTRICAL EQUIPMENT SHELTER	PANEL, CONTROL
AAABO	OA-8451 COMMUNICATIONS GROUP ELECTRICAL EQUIPMENT SHELTER	PANEL, DISTRIBUTION
AAACO	OA-8451 COMMUNICATIONS GROUP ELECTRICAL EQUIPMENT SHELTER	POWER ENTRY BOX
ABABO	OA-8452 OPERATIONS CENTRAL GROUP ELECTRICAL EQUIP SHELTER	POWER ENTRY BOX

The allocated R/M numerics for the AN/TSC-60(V) power distribution networks were extracted from references 29-31. The WUCs that were used to derive the achieved R/M numerics are: AABOO and ABBOO. Both of these WUCs are described as Power Distribution Installations. The same WUCs are used on the AN/TSC-60(V)-1, -2 and -3.

Confidence limits were calculated using the following equations:

Two-sided confidence interval

$$UL = \frac{2T}{\chi^2_{2r,\ 1-(1-P)/2}}$$

$$LL = \frac{2T}{\chi^2_{2r+2,\ (1-P)/2}}$$

single-sided confidence limit

$$LL = \frac{2T}{\chi^2_{2r+2,\ (1-P)}}$$

where χ^2 = Chi-square
r = number of failures
P = confidence level
T = total time

Mean-Time-To-Repair (MTTR) was calculated by summing the individual active repair times (clock hours) for unscheduled maintenance actions and dividing by the total number of maintenance actions.

Mean Down Time (MDT) was calculated by summing the MTTR and the mean wait time.

The Maintenance Ratio (MR) for the IPT equipments was calculated by dividing the total active clock hours repair time by the total number of operating hours. The MR for the second survey equipment was calculated by summing the total time to repair (clock hours) with an average scheduled maintenance time derived from the IPT data and dividing by the total operate time for the equipment. The average was derived by the following equation:

Scheduled Maintenance Time (Hours) = [(Total Scheduled Maintenance Time (Clock-Hours) for IPT)/(Total Operate Hours For IPT)] X Total Operate Time for equipment

For example, the MR for the A/E32C-24 equals:

$$MR = (124.4/51072) + ((132.5 \times 51072)/(36305 \times 51072) = .0024 + .0036 = .0060$$

As can be seen from the example the scheduled MR contribution for all of the equipments is 0.0036. This correction factor was required because scheduled maintenance times were not reported on the survey. Since the equipments included in the IPT are similar to the surveyed equipments, and since the equipments were kept on IPT for an average of 8.9 months, the IPT scheduled maintenance time should be a reasonable estimate of the scheduled maintenance for the surveyed equipments.

Availability was calculated by several different methods. The first method is a measure of inherent availability (Aa), that is, an estimate of the probability that an equipment will be up or down due to failures and active repair time. It is calculated by the equation:

$$A_a = MTBF/(MTBF + MTTR)$$

The second method is a measure of the actual number of times an equipment failed to start or failed at startup. It is calculated by the equation:

$$A_s = 1 - (A/S)$$

where A = number of failures at startup for ECUs or number of failures to start for power equipments

S = total number of failures for ECUs or total number of attempts to start for power equipments

The third method is taken from the Equipment Status Reports (ESR) and is a measure of the equipments ability to perform its mission. This estimate was only obtained for the A/E24U-8.

Average switchover time is an estimate of the amount of time required to switch ECU or power generating equipments. It is important if a single equipment is providing power or air conditioning and redundant equipments are available, because it gives an estimate of downtime for the system. When combined with the percent of failures where the electrical equipment had to be shut off because of failure, it provides another estimate of system downtime and consequently availability.

3.3.1.1 ECU Equipment Results

The following ECU equipment-attributes satisfied the definition of an adverse impact:

EQUIPMENT	ATTRIBUTE
A/E32C-18	MTBM MTTR R
A/E32C-23	MTBM MTTR R
A/E32C-24	MTTR
A/E32C-26	MTTR
A/E32C-27	MTTR
A/E32C-39	MTBM R
ALL A/E32C	MTTR

As can be seen by the list, the major contributor is MTTR. Since the standard that the equipments were compared with was based on maintenance actions conducted by trained test personnel at a test facility, it is not surprising that the field numeric exceeded the standard. Of the ECU's that did not meet the MTBM, MTTR and R standard, one, the A/E32C-39, was data limited in that zero failures occurred and although the other two, A/E32C-18 and A/E32C-23, failed to meet the IPT standard, they did exceed the MIL-A-38839D requirement indicating that they would have passed a reliability demonstration test. The largest impact appears to be in the amount of time associated with waiting for parts (one month average). There is no standard to judge this time against. It should be noted that only 4% of the failures resulted in the system having to be shut down. This result is significant in that it indicates that the ECU equipment functional MTBF is 47,672 hours.

3.3.1.2 Power Equipment Results

The following power equipment-attributes satisfied the definition of an adverse impact:

EQUIPMENT	ATTRIBUTE
A/E24U-8	MTBM MTTR R
MB-15	MTBM MTTR R A
MEP005	MTBM MTTR R
MEP006	MTBM MTTR R
MD-2	MTBM
MD-4	MTTR
ALL ENGINE GENERATORS	MTBM MTTR R
ALL MOTOR GENERATORS	MTTR
ALL POWER EQUIPMENT	MTBM MTTR

The major contributors for engine generators and power equipment in general are MTBM and MTTR. The major contributor for motor generators is MTTR. The average amount of time waiting for parts is 16 days (>376 hours). If this time were included in the availability calculation, none of the equipments would meet the availability requirement. In fact, the wait time for the A/E24U-8, MB-15, MEP005 and MEP005 is greater than the MTBM calculation; therefore, the calculated inherent availability would be less than zero.

3.3.1.3 Power Distribution Network (PDN) Results

The following PDN equipment-attributes satisfied the definition of an adverse impact:

EQUIPMENT	ATTRIBUTE
AN/TSC-60(V)-1	MTBM MTTR
AN/TSC-60(V)-2	MTBM MTTR
AN/TSC-60(V)-3	MTBM MTTR
AN/TSQ-91	MTBM MTTR
AN/TSQ-92	MTBM

All of the equipments failed to meet the standard for MTBM, and all of the equipments except the AN/TSQ-92 failed to meet the standard for MTTR. The AN/TSQ-92 MTBM result is pessimistic since it is limited by the fact that zero maintenance events occurred and since the allocated MTBM numeric is optimistic in that not all of the power distribution equipments were included in the allocation.

3.3.2 Ground Tactical C^3I Systems

This section presents the analyses of the achieved R/M of ancillary E/M equipments as a percentage of the system R/M. The achieved Mean Time Between Maintenance Events (MTBME), Mean Maintenance Manhours To Repair (MMMR) and Availability (A_a) R/M numerics were analyzed from various field experience reports and the percent system R/M contribution of the ancillary E/M equipments was calculated. This percentage was then compared with the percentage anticipated by the specified and/or predicted values. An adverse effect was defined as a higher achieved percentage than the percentage derived from the specified R/M numerics. The predicted value was used if the specified value was not available. The analyses are presented by system type in the following sections.

Field experience data were obtained from D056B5503, TAC BLIS and TAC ESR reports and the Second Survey. The D056B5503 and TAC BLIS reports are generated for a specific calendar period and contain maintenance actions and times to perform the maintenance actions. They do not contain the operating times accrued by the equipments during the period. Since specified MTBF, MTBM, MTBME and A_a numerics are based on operating time, and since the data for the power and ECU equipments were generated from an entirely different data source and covering a different calendar period, it was believed that more reliable comparsions could be made by utilizing achieved R/M numerics based on operating hours. The estimates of operating time were derived from information obtained from Survey One (ref 43) and equipment inventory data obtained from the Item Managers. The estimate was derived by calculating an average number of operating hours per calendar year from the reference 43 information and then multiplying this average by the inventory. The equipment inventories and information used to derive the average operating hour estimate is given in the following appropriate sections.

An estimate of achieved R/M was derived based on possessed hours. This estimate was used to gage the amount of maintenance activity and therefore the impact of failures and maintenance over a calendar period.

The specified, predicted and demonstrated MTBF, and the predicted and demonstrated MTTR and A_a were obtained from R/M Contract Data Requirement Submittals (CDR). In many cases specific R/M numerics were not available directly from the CDR reports and had to be calculated. In other cases the system level specified, predicted and demonstrated R/M numerics did not contain provisions for the power and ECU equipments; therefore, the R/M numerics had to be revised to include them. The method of calculation and assumptions made to derive the missing and revised R/M numerics are given in the appropriate section below.

It was assumed that the data given for the Electronic Equipment characteristics on the D056B5503 and TAC BLIS reports for both the AN/TSC-60(V) and AN/TSQ-XX systems was the difference between the total system data minus the power distribution and ECU data. The field experience data for the power equipments were not part of these reports.

The achieved R/M comparison numerics for the equipments were calculated as follows:

<u>TAC BLIS</u>

MTBM = Mean Time Between Maintenance Events (MTBME)
MTTR = (Total Maintenance Manhours)/(Total Maintenance Events)
A_a = MTBM/(MTBM + MTTR)

<u>D056B5503</u>

MTBM = MTBME = (Total Operate Hours/Year)/(Total Events)
MTTR = MMMR = (Total Maintenance Manhours)/(Total Events)
A_a = MTBM/(MTBM + MTTR)

The Chi-square method was used to derive confidence intervals about the MTBM point estimate. The data from the second survey was used to derive the power equipment achieved R/M numerics that were used for the percentage calculation.

The achieved point estimate R/M numeric was used for the percentage calculations as statistically it is the best estimate. The Chi-square 60% confidence limit was utilized for those cases where zero maintenance events occurred. The 60% confidence limit was used because it is not as pessimistic as assuming one failure occurred (63% confidence limit). The predicted and demonstrated R/M numerics are given, if known. They were not used for the percentage calculation unless a specified value was not given. The order of precedence used for the percentage calculations was: (1) specified, (2) predicted and (3) demonstrated.

A high percentage of the D056B5503 maintenance events were classified as failures. This tends to contradict other sources that report that 23% of field maintenance actions are failures (ref 51) or 2-43% (ref 42). These D056B5503 data would tend to give a pessimistic value for the achieved R/M; however, for the purpose of this study we can assume that the biases apply uniformly to the electronic, ECU and power distribution equipments; therefore, the percentage of system maintenance attributed to the electronic, ECU and power distribution equipments would be the same as if no bias were present. The percent contribution due to power generation (conversion) equipment may be biased against power generation (conversion) equipment since the power generation (conversion) equipment R/M numerics were derived from data collected during the second survey and these data should contain less errors.

3.3.2.1 AN/TSC-60(V) Analysis

The current Air Force inventory was obtained from the Item Manager at SM-ALC on 9 February 1982. The inventory is the following:

EQUIPMENT	AIR FORCE	TACTICAL AIR COMMAND (TAC)
AN/TSC-60(V)-1	58	12
AN/TSC-60(V)-2	57	0
AN/TSC-60(V)-3	15*	0
TOTAL	130	12

* Quantity is for OZ-11 10kw Transmitter

The information used to derive the average operating time is given in Table 3.3.2-1. Two averages were calculated. One for TAC units and one for all Air Force units. The TAC operating time estimate was derived from the four TAC units and was used to develop the R/M numerics for the field experience data given in the TAC BLIS report. The operating time estimate derived from all the Air Force units was used to develop the R/M numerics for the field experience data given in the D056B5503 reports since all Air Force units including Air National Guard provide data for this report.

TABLE 3.3.2-1: AN/TSC-60(V) OPERATING TIME INFORMATION

UNIT	PER EQUIPMENT HRS HOME	HRS DEPLOY	TOTAL HRS	#EQUIPM	TOTAL OF HRS	UNIT TYPE
5thTAIRGG	390	0	390	2	780	AF
1961COMMGP	2160	1228.8	3389	2	6778	AF
604DASS	360	1056	1416	1	1416	AF
239CCF/241ATCF	192	--	192	1	192	ANG
223CMBTCS	150	612	762	2	1524	ANG
224CMBTCS	700	1440	2140	1	2140	ANG
244CMBTCF	600	3360	3960	1	3960	ANG
263CMBTCS	90	96	186	1	186	ANG
229TCS	2160	360	2520	3	7560	ANG
222CMBTCS	24	2880	2904	2	5808	ANG
264CMBTCS	--	960	960	1	960	ANG
261CMBTCS	600	1440	2040	1	2040	ANG
103TCS	600	576	1176	3	3528	ANG
265CMBTCS	200	360	560	1	560	ANG
226CMBTCS	1200	1296	2496	4	9984	ANG
111CEMSQ	1600	1188	2788	1	2788	ANG
267CMBTCS	240	--	240	4	960	ANG
105TCS	720	396	1116	3	3348	ANG
1CMBTCS	800	4320	5120	3	15360	AF
603TCS	5840	1680	7520	6	45720	AF
101TCS	--	432	432	3	1296	ANG
256CMBTCS	256	2160	2416	2	4832	ANG
606TCS	3960	1728	5688	4	22752	AF
727TCS	800	2160	2960	2	5920	AF TAC
3RDCMBTCG	1000	1608	2608	6	15648	AF
507TACCS	--	2664	2664	4	10656	AF TAC
682ASOC	960	1848	2808	1	2808	AF TAC
105CEM	400	1080	1480	1	1480	ANG
107TCS	1620	1080	2700	3	8100	ANG
244CMBTCS	360	1440	1800	1	1800	ANG
234CMBTCS	600	1188	1788	2	3576	ANG
621TCS	160	0	160	2	320	AF
728TCS	2400	1344	3744	3	11232	AF TAC
2CMBTCG	1440	2268	3708	4	14832	AF
217CMBTCS	160	306	466	2	932	ANG
				83	221176	

Figure 3.3.2-1 gives a simplified reliability block diagram (RBD) and reliability math model (RMM) for the AN/TSC-60(V) equipments. The diagrams and models depict a logistics configuration wherein it is assumed that if any unit fails the system fails. The term "logistics" comes from the fact that the model can be used to derive a good estimate of the number of maintenance actions that will be required. A functional RBD and RMM includes redundancy and can be used to derive a good estimate of mission reliability. The Collins R/M reports (ref 28 - 30) contain functional RMM and RBDs for the AN/TSC-60(V) equipments. The logistics R/M numerics were used for this study because the data available from the field maintenance reports could be used to generate reasonably accurate comparisons for logistics R/M numerics, but could not be relied upon to provide information on system mission capability. Any mission capability data collected during the study are discussed in the appropriate section.

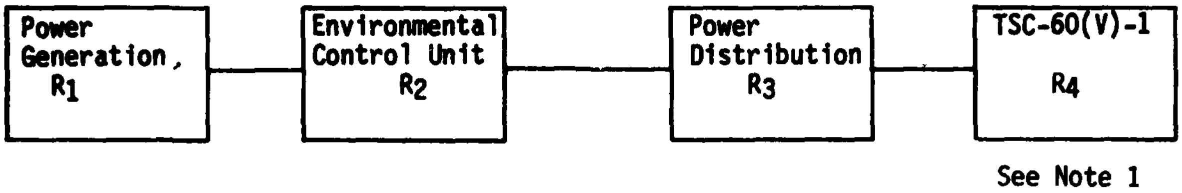
References 28 - 30 did not provide specified, predicted or demonstrated Mean-Time-To-Repair estimates for the AN/TSC-60(V) electronic equipment. The estimate used in the analyses was a pseudo predicted value that was derived as a weighted average of the individual equipments by the following equation:

$$\text{MTTR (Electronic System)} = \frac{\sum_{i=1}^{n} \left((\text{Failure rate})_i \times \text{MTTR}_i\right)}{\sum_{i=1}^{n} (\text{Failure rate})_i}$$

References 28 - 30 did not provide a specified or allocated MTBF value for the power distribution network (PDN). The allocated estimate used in the analysis was derived by the following equation:

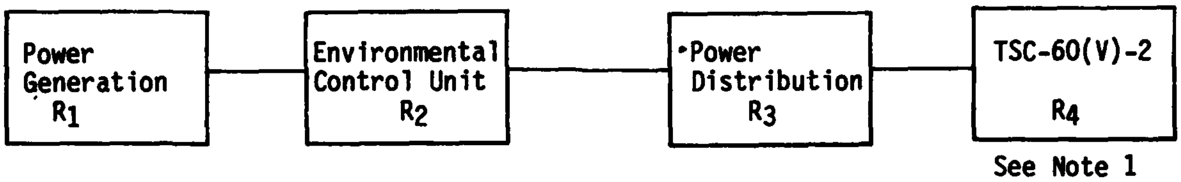
$$\text{MTBF(PDN, ALLOCATED)} = \frac{\text{MTBF (Systems, Specified)}}{\text{MTBF (System, Predicted)}} \times \text{MTBF (PDN, Predicted)}$$

The power distribution network for the AN/TSC-60(V) equipments is defined as WUCs AAB00 and ABB00.



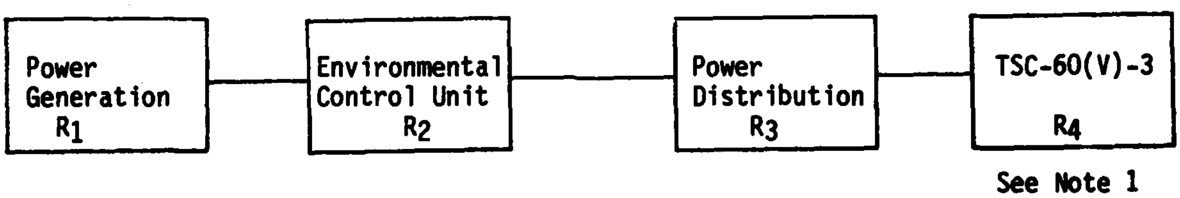
Reliability Math Model: $R_S = R_1 R_2 R_3 R_4$

TSC-60(V)-1



Reliability Math Model: $R_S = R_1 R_2 R_3 R_4$

TSC-60(V)-2



Reliability Math Model: $R_S = R_1 R_2 R_3 R_4$

TSC-60(V)-3

Note 1 - The TSC-60(V) Power Distribution System is included in the Power Distribution Block and excluded from the TSC-60(V) block.

FIGURE 3.3.2-1: RELIABILITY BLOCK DIAGRAMS AND MATH MODELS OF TSC-60(V)-1,2,3

The RBD, RMM and R/M numerics given in references 28 - 30 did not provide for power and ECU equipments as part of the AN/TSC-60(V) systems. The specified and predicted MTBF numerics provided in the reference were revised so that they reflected the incorporation of the power and ECU equipment by the following equation:

$$\frac{1}{\text{MTBF(System)}} = \frac{1}{\text{MTBF(System, OLD)}} + \frac{1}{\text{MTBF(ECU)}} + \frac{1}{\text{MTBF(Power)}}$$

The specified MTTR estimate for the AN/TSC-60(V) systems were revised so that they reflected the incorporation of the power and ECU equipment. The estimate was derived as a weighted average of the power, ECU and electronics by the following equation:

$$\text{MTTR (System)} = \frac{\sum_{i=1}^{n} ((\text{Failure rate})_i \times \text{MTTR}_i)}{\sum_{i=1}^{n} (\text{Failure rate})_i}$$

The specified MTBFand MTTR estimates for the power and ECU equipments were obtained from the equipment specification if the numeric was called out in the specification or from data extracted from the Initial Production Test (IPT) reports (ref 2 - 18). The AN/TSC-60(V) system operates with two different types of power equipment - power generation or power conversion. The specified MTBF, MTTR and A_a system level estimates were revised utilizing both types of power. The power and ECU equipment R/M numerics are averages of the types used with the system, and were obtained by calculating the R/M numerics from the data obtained during the second survey. The AN/TSC-60(V) utilizes the A/E32C-24, -25 and -27 ECUs; the EMU-21, -22, A/E24U-8, MB-15, MEP005 and MEP006 power generation units;

and the MD-4 power conversion unit. The ECU and power R/M numerics for the equipments used with the AN/TSC-60(V) equipments are:

EQUIPMENT	TYPE	QTY	R/M NUMERIC MTBF		MTTR		A_o	
			SPECIFIED	ACHIEVED	SPECIFIED	ACHIEVED	SPECIFIED	ACHIEVED
ECU	ALL	202	434	1757	2.5(1)	4.5	0.95	0.9974
Power Generator	MB-15	23	1000	35.5	2.0	4.2	--	0.8942
	MEP005	25	335	308	--	4.0	--	0.9872
	MEP006	7	250	154	--	3.0	--	0.9809
	EMU-30	134	500	167	--	6.3	--	0.9636
	TOTAL	189	530	88.8	2.0	5.7	0.90(2)	0.9397
Power Conversion	MD-4		4000	1745	0.5	44.7	0.90(2)	0.9750

NOTES:

(1) From results of IPT tests. A predicted value based on similar equipment.
(2) Average from IPT requirements

3.3.2.2 AN/TSC-60(V)-1 Analysis

The field experience data summarized from the TAC BLIS report is given below. These data cover the twelve month calendar period August 1980 to August 1981 for twelve AN/TSC-60(V)-1 systems.

CHARACTERISTIC	SYSTEM	ELECTRONIC EQUIPMENT	POWER DISTRIBUTION	ECU
Total Maintenance Events	134	130	1	3
Total Maintenance Actions	279	273	1	5
Maintenance Events with System Downtime	6	6	0	0
Total Maintenance Manhours	1624.1	1613.6	0.5	10.0
Maintenance Manhours with System Down time	182.3	182.3	0	0
Average Operate hours/year	3061.6	3061.6	3061.6	3061.6
Total operate hours/year	36739.2	36739.2	36739.2	36739.2
Mean Time Between Maintenance Events (MTBME) (Hours)	274	283	36739	12246
Mean Time Between System Downtime	6123.2	6123.2	--	--

As can be seen by the data presented above, there is an average of over two maintenance actions for each maintenance event. This is one reason why it is imperative that maintenance events be identified and used to assess the achieved R/M rather than the number of maintenance actions. It can also be seen that only 4.4% of the maintenance events resulted in system downtime; therefore, MTBME should not be used to assess the achieved mission reliability unless the events can be further qualified to determine if system downtime resulted from the event. The power distribution and ECU equipment did not cause any system downtime during this reporting period.

The field experience data summarized from the D056B5503 report was given below. This data covers a twelve month reporting period for fifty-eight (58) AN/TSC-60(V)-1 equipments.

CHARACTERISTIC	SYSTEM	ELECTRONIC EQUIPMENT	POWER DISTRIBUTION	ECU
FAILURES	1302	1255	4	43
OTHER MALFUNCTIONS	37	35	0	2
NO DEFECT	0	0	0	0
TOTAL EVENTS	1399	1290	4	45
MAINTENANCE MAN HOURS	7371.6	7094.5	16.6	260.5
AVERAGE OPHRS/YEAR	2664.8	2664.8	2664.8	2664.8
TOTAL OPERATE HOURS	154558	154558	154558	154558
TOTAL POSSESSION HOURS	508080	508080	508080	508080

As can be seen by the data presented above 93% of field maintenance actions are classifed as failures.

The data used for the percentage calculations are presented in Table 3.3.2-2.

TABLE 3.3.2-2: AN/TSC-60(V)-1 R/M NUMERICS

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	2ND SURVEY	TAC BLIS	D056B5503	ESR	NOTES
SYSTEM	MTBM (OPERATE HOURS)								
	POINT ESTIMATE	142/185	234	261		67.1/237	50.2/108		5, 6, 9, 10, 11, 12, 13
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					57.2/196	44.5/99.0		11, 12, 13
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					78.9/286	56.5/122		11, 12, 13
	SINGLE-SIDED 90% CONFIDENCE LIMIT					59.2/204	45.8/102		11, 12, 13
	SINGLE-SIDED 60% CONFIDENCE LIMIT								
	MTBM (POSSESSED HOURS)								
	POINT ESTIMATE					617/624	336/338		11, 12, 13
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					511/485	317/307		11, 12, 13
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					720/771	359/371		11, 12, 13
	SINGLE-SIDED					532/510	318/310		
	MTTR (CLOCK-HOURS)		1.1	1.1					9, 10
	(MAN HOURS)					7.3/16.5	5.6/7.9		11, 12, 13
	AVAILABILITY (Aa)	0.839	0.9953	0.9959		0.8999/0.9337	0.8969/0.9306	0.842	9, 10, 11, 12, 13, 14, 15
ELECTRONICS	MTBM (OPERATE HOURS)								
	POINT ESTIMATE	352	432			283	120		1
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					224	114		
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					328	126		
	SINGLE-SIDED 90% CONFIDENCE LIMIT			213		252	116		
	SINGLE-SIDED 60% CONFIDENCE LIMIT			532					
	MTBM (POSSESSED HOURS)								
	POINT ESTIMATE					809	394		
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					699	376		
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					940	412		
	SINGLE-SIDED 90% CONFIDENCE LIMIT					721	380		
	MTTR (CLOCK-HOURS)		0.3	0.1					
	(MAN HOURS)					12.4	5.5		
	AVAILABILITY (Aa)		0.9993	0.9998		0.9580	0.9562		

TABLE 3.3.2-2: AN/TSC-60(V)-1 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	2ND SURVEY	TAC BLIS	D05685503	ESR	NOTES
POWER - DISTRI- BUTION	MTBM (OPERATE HOURS)								
	POINT ESTIMATE	73500	90300			36739	38640		1
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					7743	16882		
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					716164	113230		
	SINGLE-SIDED 90% CONFIDENCE LIMIT			213		9444	19332		
	SINGLE-SIDED 60% CONFIDENCE LIMIT			532					
	MTBM (POSSESSED HOURS)								
	POINT ESTIMATE					105120	127020		
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					22154	55498		
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					2049123	372220		
	SINGLE-SIDED 90% CONFIDENCE LIMIT					27023	63550		
	SINGLE-SIDED 60% CONFIDENCE LIMIT								
	MTTR (CLOCK-HOURS)		0.2						
	(MAN HOURS)					0.5	4.2		
	AVAILABILITY (Aa)		0.9999			0.9999	0.9999		
ECU	MTBM (OPERATE HOURS)								
	POINT ESTIMATE			885	1757	12246	3435		2
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			682	1400	4737	2679		2
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			1169	2232	44804	4472		2
	SINGLE-SIDED 90% CONFIDENCE LIMIT	434		719	1474	5500	2816		2, 6
	SINGLE-SIDED 60% CONFIDENCE LIMIT			532					2
	MTBM (POSSESSED HOURS)								
	POINT ESTIMATE			6670	9292	35040	11291		2
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			5141	7405	13555	8806		2
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			8803	11806	128195	14701		2
	SINGLE-SIDED 90% CONFIDENCE LIMIT					15736	9258		2
	SINGLE-SIDED 60% CONFIDENCE LIMIT								
	MTTR (CLOCK-HOURS)		0.2	2.5	4.5				2
	(MAN HOURS)					3.3	5.8		
	AVAILABILITY (Aa)			0.9972	0.9974	0.9997	0.9983		

TABLE 3.3.2-2: AN/TSC-60(V)-1 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	2ND SURVEY	TAC BLIS	D056B5503	ESR	NOTES
POWER GEENRATION	MTBM (OPERATE HOURS)								
	POINT ESTIMATE	530		1221/222	88.8				2, 4, 6, 8
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			677/182	75.4				2, 8
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			2454/290	105				2, 8
	SINGLE-SIDED 90% CONFIDENCE LIMIT			752/173	78.0				2, 8
	SINGLE-SIDED 60% CONFIDENCE LIMIT								
	MTBM (POSSESSED HOURS)								
	POINT ESTIMATE			6135	2901				2
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			3400	2461				2
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			12332	3441				2
	SINGLE-SIDED 90% CONFIDENCE LIMIT				2546				2
	MTTR (CLOCK-HOURS)	2.0		1.4	5.7				2
	(MAN HOURS)			1.8					2
	AVAILABILITY (Aa)	0.9962		0.9989	0.9397			0.971	2, 16
POWER CONVERSION	MTBM (OPERATE HOURS)								
	POINT ESTIMATE	4000/400		1221/222	1754				2, 6, 7, 8
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			677/182	1116				2, 8
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			2454/290	2888				2, 8
	SINGLE-SIDED 90% CONFIDENCE LIMIT			752/173	1214				2, 8
	MTBM (POSSESSED HOURS)								
	POINT ESTIMATE			6135	3051				2
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			3400	1952				2
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			12332	5050				2
	SINGLE-SIDED 90% CONFIDENCE LIMIT				2122				2
	MTTR (CLOCK-HOURS)	0.5		1.4	44.7				2
	(MAN HOURS)	1.0		1.8					2
	AVAILABILITY (Aa)	0.9999		0.9989	0.9750				2

TABLE 3.3.2-2: AN/TSC-60(V)-1 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	2ND SURVEY	TAC BLIS	D05685503	ESR	NOTES

NOTES:

1) SPECIFIED IS AN ALLOCATED NUMERIC
2) DEMONSTRATED IS AN AVERAGE FROM IPT EQUIPMENTS
3) IPT REQUIREMENT
4) SPECIFIED IS A WEIGHTED AVERAGE
5) SPECIFIED INCLUDES ECU & POWER GENERATION/ECU & POWER CONVERSION SPECIFIED NUMERICS
6) SPECIFIED IS MTBF
7) SPECIFIED IS MTBF/MTBM
8) DEMONSTRATED IS AN AVERAGE FROM IPT EQUIPMENTS BASED ON CHARGEABLE FAILURES/ALL MALFUNCTIONS
9) DEMONSTRATE IS BASED ON DEMONSTRATED NUMERICS FOR THE SEPARATE EQUIPMENTS. NO SYSTEM LEVEL TEST DATA WERE AVAILABLE.
10) PREDICTED IS BASED ON DEMONSTRATED NUMERICS FOR THE ECU AND POWER EQUIPMENTS AND PREDICTED NUMERICS FOR THE ELECTRONICS AND POWER DISTRIBUTION
11) ACHIEVED TAC BLIS IS BASED ON TAC BLIS FOR ALL EXCEPT POWER. POWER IS BASED ON SECOND SURVEY
12) ACHIEVED IS FOR SYSTEM WITH POWER GENERATION/POWER CONVERSION
13) ACHIEVED D05685503 IS BASED ON D05685503 FOR ALL EXCEPT POWER. POWER IS BASED ON SECOND SURVEY
14) SPECIFIED AVAILABILITY IS TAC REQUIREMENT FROM ESR REPORT FOR ALL AN/TSC-60(V)
15) ACHIEVED ESR IS FOR ALL TAC AN/TSC-60(V) EQUIPMENTS
16) SPECIFIED AND ACHIEVED AVAILABILITY FOR A/E24U-8 FROM TAC ESR

3.3.2.3 AN/TSC-60(V)-1 Results

The percent specified (predicted) and achieved MTBF, MTTR and A_a contribution of the power, ECU, power distribution and electronic equipments to the AN/TSC-60(V)-1 system is given below for the three report types:

TAC BLIS REPORT

EQUIPMENT	PERCENT CONTRIBUTION MTBF (1)		MTTR (2)		A_a	
	SPECIFIED	ACHIEVED	PREDICTED	ACHIEVED	PREDICTED	ACHIEVED
WITH POWER GENERATION						
ELECTRONICS	40.3	23.7	15.0	40.4	14.9	40.7
POWER DISTRIBUTION	0.2	0.2	0.1	0.1	0.2	0.1
ECU	32.7	0.5	60.3	0.3	59.5	0.3
POWER GENERATION	26.8	75.6	24.6	59.2	23.4	58.9
WITH POWER CONVERSION						
ELECTRONICS	52.6	83.8	15.0	62.9	14.9	62.5
POWER DISTRIBUTION	0.2	0.7	0.1	0.1	0.2	0.1
ECU	42.6	1.9	60.3	0.4	59.5	0.5
POWER CONVERSION	4.6	13.6	24.6	36.6	23.4	36.9

Notes: 1) Achieved is MTBME
2) Achieved is MMMR

D056B5503 REPORT

EQUIPMENT	PERCENT CONTRIBUTION MTBF (1)		MTTR (2)		A_a	
	SPECIFIED	ACHIEVED	PREDICTED	ACHIEVED	PREDICTED	ACHIEVED
WITH POWER GENERATION						
ELECTRONICS	38.8	41.8	15.0	41.1	14.9	41.2
POWER DISTRIBUTION	0.2	0.1	0.1	0.1	0.2	0.1
ECU	31.6	1.5	60.3	1.5	59.5	1.6
POWER GENERATION	29.4	56.6	24.6	57.3	23.4	57.1
WITH POWER CONVERSION						
ELECTRONICS	52.6	90.5	15.0	62.7	14.9	62.3
POWER DISTRIBUTION	0.2	0.3	0.1	0.1	0.2	0.1
ECU	42.6	3.1	60.3	2.3	59.5	2.4
POWER CONVERSION	4.6	6.2	24.6	34.9	23.4	35.2

Notes: 1) Achieved is MTBME
2) Achieved is MMMR

The results indicate the ECU and power distribution equipments do not have an adverse impact on the system R/M. The power generation and power conversion equipments do have an adverse impact. These results were obtained from both the TAC BLIS and the D056B5503 reports. Since none of the ECU or power distribution equipment failures resulted in system downtime, the failures had no impact on the system functional reliability.

ESR REPORT (AVAILABILITY)

	SPECIFIED	TAC STANDARD	ACHIEVED
TSC-60(V)	0.839	0.92	0.842

3.3.2.4 AN/TSC-60(V)-2 Analysis

The field experience data summarized from the D056B5503 report are given below. This data covers a twelve month reporting period for fifty-seven (57) AN/TSC-60(V)-2 equipments.

CHARACTERISTIC	SYSTEM	ELECTRONIC EQUIPMENT	POWER DISTRIBUTION	ECU
FAILURES	653	624	10	19
OTHER MALFUNCTIONS	38	37	0	1
NO DEFECT	0	0	0	0
TOTAL EVENTS	691	661	10	20
MAINTENANCE MAN HOURS	3406.8	3306.8	17.9	82.1
AVERAGE OPHRS/YEAR	2664.8	2664.8	2664.8	2664.8
TOTAL OPERATE HOURS	151894	151894	151894	151894
TOTAL POSSESSION HOURS	499320	499320	499320	499320

As can be seen by the data presented above 94.5% of field maintenance actions are failures.

The AN/TSC-60(V)-2 field experience data used for the percentage calculations are presented in Table 3.3.2-3. The specified, predicted and demonstrated R/M numerics for the power equipment are presented in Table 3.3.2-2.

TABLE 3.3.2-3: AN/TSC-60(V)-2 R/M NUMERICS

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	D056B5503	ESR	NOTES
SYSTEM	MTBM (OPERATE HOURS)						
	POINT ESTIMATE	131/166	232	278	63.3/195		4, 5, 6, 7, 8, 9
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				54.9/171		8, 9
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				72.8/220		8, 9
	SINGLE-SIDED 90% CONFIDENCE LIMIT				56.5/176		8, 9
	SINGLE-SIDED 60% CONFIDENCE LIMIT						
	MTBM (POSSESSED HOURS)						
	POINT ESTIMATE				578/584		8, 9
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				523/496		8, 9
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				637/677		8, 9
	SINGLE-SIDED				535/513		
	MTTR (CLOCK-HOURS)		1.1	1.2			6, 7
	(MAN HOURS)				5.5/9.3		8, 9
	AVAILABILITY (Aa)	0.839	0.9953	0.9958	0.9191/0.9537	0.842	6, 7, 8, 9, 10, 11,
ELECTRONICS	MTBM (OPERATE HOURS)						
	POINT ESTIMATE	291	427	609	230		1, 6
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			128	215		
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			11871	245		
	SINGLE-SIDED 90% CONFIDENCE LIMIT			157	218		
	SINGLE-SIDED 60% CONFIDENCE LIMIT						
	MTBM (POSSESSED HOURS)						
	POINT ESTIMATE				755		
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				708		
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				806		
	SINGLE-SIDED 90% CONFIDENCE LIMIT				718		
	MTTR (CLOCK-HOURS)		0.3	0.2			
	(MAN HOURS)				5.0		
	AVAILABILITY (Aa)		0.9993	0.9997	0.9787		

TABLE 3.3.2-3: AN/TSC-60(V)-2 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	D056B5503	ESR	NOTES
POWER DISTRI-BUTION	MTBM (OPERATE HOURS)						
	POINT ESTIMATE	61616	90300		15189		1, 5
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				8956		
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				27999		
	SINGLE-SIDED 90% CONFIDENCE LIMIT			264	9863		
	SINGLE-SIDED 60% CONFIDENCE LIMIT			660			
	MTBM (POSSESSED HOURS)						
	POINT ESTIMATE				49932		
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				29441		
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				92041		
	SINGLE-SIDED 90% CONFIDENCE LIMIT				32423		
	SINGLE-SIDED 60% CONFIDENCE LIMIT						
	MTTR (CLOCK-HOURS)		0.2				
	(MAN HOURS)				1.8		
	AVAILABILITY (Aa)		0.9999		0.9999		
ECU	MTBM (OPERATE HOURS)						
	POINT ESTIMATE			885	7595		2
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			682	5227		2
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			1169	11459		2
	SINGLE-SIDED 90% CONFIDENCE LIMIT	434		719	5616		2, 5
	SINGLE-SIDED 60% CONFIDENCE LIMIT						2
	MTBM (POSSESSED HOURS)						
	POINT ESTIMATE			6670	24966		2
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			5141	17182		2
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			8803	37670		2
	SINGLE-SIDED 90% CONFIDENCE LIMIT				18463		2
	SINGLE-SIDED 60% CONFIDENCE LIMIT						
	MTTR (CLOCK-HOURS)			2.5			2
	(MAN HOURS)				4.1		
	AVAILABILITY (Aa)			0.9972	0.9975		

TABLE 3.3.2-3: AN/TSC-60(V)-2 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	D05685503	ESR	NOTES

NOTES:

1) SPECIFIED IS AN ALLOCATED NUMERIC
2) DEMONSTRATED IS AN AVERAGE FROM IPT EQUIPMENTS
3) SPECIFIED IS A WEIGHTED AVERAGE
4) SPECIFIED INCLUDES ECU & POWER GENERATION/ECU & POWER CONVERSION SPECIFIED NUMERICS
5) SPECIFIED IS MTBF
6) DEMONSTRATE IS BASED ON DEMONSTRATED NUMERICS FOR THE SEPARATE EQUIPMENTS. NO SYSTEM LEVEL TEST DATA WERE AVAILABLE.
7) PREDICTED IS BASED ON DEMONSTRATED NUMERICS FOR THE ECU AND POWER EQUIPMENTS AND PREDICTED NUMERICS FOR THE ELECTRONICS AND POWER DISTRIBUTION
8) ACHIEVED IS FOR SYSTEM WITH POWER GENERATION/POWER CONVERSION
9) ACHIEVED D05685503 IS BASED ON D05685503 FOR ALL EXCEPT POWER. POWER IS BASED ON SECOND SURVEY
10) SPECIFIED AVAILABILITY IS TAC REQUIREMENT FROM ESR REPORT FOR ALL AN/TSC-60(V)
11) ACHIEVED ESR IS FOR ALL TAC AN/TSC-60(V) EQUIPMENTS

3.3.2.5 AN/TSC-60(V)-2 Results

The percent specified (predicted) and achieved MTBF, MTTR and A_a contribution of the power, ECU, power distribution and electronic equipments to the AN/TSC-60(V)-2 system is given below:

D056B5503 REPORT

EQUIPMENT	PERCENT CONTRIBUTION MTBF (1)		MTTR (2)		A_a	
	SPECIFIED	ACHIEVED	PREDICTED	ACHIEVED	PREDICTED	ACHIEVED
WITH POWER GENERATION						
ELECTRONICS	45.0	27.5	14.8	25.2	14.9	25.5
POWER DISTRIBUTION	0.2	0.4	0.1	0.1	2.1	0.1
ECU	30.2	0.8	59.8	0.6	59.6	0.6
POWER GENERATION	24.6	71.3	24.3	74.1	23.4	73.8
WITH POWER CONVERSION						
ELECTRONICS	57.3	85.0	14.8	45.5	14.9	45.4
POWER DISTRIBUTION	0.3	1.3	0.1	0.1	2.1	0.2
ECU	38.2	2.6	59.8	1.1	59.6	1.0
POWER CONVERSION	4.2	1.1	24.3	53.3	33.4	53.4

Notes: 1) Achieved is MTBME
2) Achieved is MMMR

The results indicate that the ECU and power distribution equipments do not have an adverse impact on the system R/M. The power generation and power conversion equipments do have an adverse impact.

3.3.2.6 AN/TSC-60(V)-3 Analysis

The field experience data summarized from the D056B5503 report are given below. This data covers a twelve month reporting period for fifteen (15) AN/TSC-60(V)-3 equipments.

CHARACTERISTIC	SYSTEM	ELECTRONIC EQUIPMENT	POWER DISTRIBUTION	ECU
FAILURES	369	349	7	13
OTHER MALFUNCTIONS	25	24	0	1
NO DEFECT	0	0	0	0
TOTAL EVENTS	394	373	7	14
MAINTENANCE MAN HOURS	2389	2261	33.9	94.1
AVERAGE OPHRS/YEAR	2664.8	2664.8	2664.8	2664.8
TOTAL OPERATE HOURS	39960	39960	39960	39960
TOTAL POSSESSION HOURS	131400	131400	131400	131400

As can be seen by the data presented above 93.6% of field maintenance actions are failures.

The AN/TSC-60(V)-3 field experience data used for the percentage calculations are presented in Table 3.3.2-4. The specified, predicted and demonstrated R/M numerics for the power equipment are presented in Table 3.3.2-2.

TABLE 3.3.2-4: AN/TSC-60(V)-3 R/M NUMERICS

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	D05685503	ESR	NOTES
SYSTEM	MTBM (OPERATE HOURS)						
	POINT ESTIMATE	157/212	246	223	47.3/95.8		4, 5, 6, 7, 8, 9
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				41.1/83.7		8, 9
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				54.4/109		8, 9
	SINGLE-SIDED 90% CONFIDENCE LIMIT				42.3/86		8, 9
	SINGLE-SIDED 60% CONFIDENCE LIMIT						
	MTBM (POSSESSED HOURS)						
	POINT ESTIMATE				299/300		8, 9
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				265/258		8, 9
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				335/346		8, 9
	SINGLE-SIDED				272/266		
	MTTR (CLOCK-HOURS)		1.1	1.0			6, 7
	(MAN HOURS)				5.9/8.2		8, 9
	AVAILABILITY (Aa)	0.839	0.9954	0.9956	0.8862/0.9195	0.842	6, 7, 8, 9, 10, 11,
ELECTRONICS	MTBM (OPERATE HOURS)						
	POINT ESTIMATE	465	479		107		1, 6
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				98.3		
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				117		
	SINGLE-SIDED 90% CONFIDENCE LIMIT			158	100		
	SINGLE-SIDED 60% CONFIDENCE LIMIT			395			
	MTBM (POSSESSED HOURS)						
	POINT ESTIMATE				352		
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				323		
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				384		
	SINGLE-SIDED 90% CONFIDENCE LIMIT				329		
	MTTR (CLOCK-HOURS)		0.3	0.2			
	(MAN HOURS)				6.1		
	AVAILABILITY (Aa)	0.9994	0.9995	0.9461			

TABLE 3.3.2-4: AN/TSC-60(V)-3 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	D056B5503	ESR	NOTES
POWER DISTRI-BUTION	MTBM (OPERATE HOURS)						
	POINT ESTIMATE	45327	46707		5709		1, 5
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				3039		
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				12164		
	SINGLE-SIDED 90% CONFIDENCE LIMIT			158	3395		
	SINGLE-SIDED 60% CONFIDENCE LIMIT			395			
	MTBM (POSSESSED HOURS)						
	POINT ESTIMATE				18771		
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				9992		
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				400[illegible]0		
	SINGLE-SIDED 90% CONFIDENCE LIMIT				11164		
	SINGLE-SIDED 60% CONFIDENCE LIMIT						
	MTTR (CLOCK-HOURS)		0.2				
	(MAN HOURS)				4.8		
	AVAILABILITY (Aa)		0.9999		0.99992		
ECU	MTBM (OPERATE HOURS)						
	POINT ESTIMATE			885	2854		2
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			682	1826		2
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			1169	4723		2
	SINGLE-SIDED 90% CONFIDENCE LIMIT	434		719	1985		2, 5
	SINGLE-SIDED 60% CONFIDENCE LIMIT						2
	MTBM (POSSESSED HOURS)						
	POINT ESTIMATE			6670	9386		2
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			5141	6004		2
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			8803	15532		2
	SINGLE-SIDED 90% CONFIDENCE LIMIT				6528		2
	SINGLE-SIDED 60% CONFIDENCE LIMIT						
	MTTR (CLOCK-HOURS)			2.5			2
	(MAN HOURS)				6.7		
	AVAILABILITY (Aa)			0.9972	0.9976		

TABLE 3.3.2-4: AN/TSC-60(V)-3 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	D05685503	ESR	NOTES

NOTES:

1) SPECIFIED IS AN ALLOCATED NUMERIC
2) DEMONSTRATED IS AN AVERAGE FROM IPT EQUIPMENTS
3) SPECIFIED IS A WEIGHTED AVERAGE
4) SPECIFIED INCLUDES ECU & POWER GENERATION/ECU & POWER CONVERSION SPECIFIED NUMERICS
5) SPECIFIED IS MTBF
6) DEMONSTRATE IS BASED ON DEMONSTRATED NUMERICS FOR THE SEPARATE EQUIPMENTS. NO SYSTEM LEVEL TEST DATA WERE AVAILABLE.
7) PREDICTED IS BASED ON DEMONSTRATED NUMERICS FOR THE ECU AND POWER EQUIPMENTS AND PREDICTED NUMERICS FOR THE ELECTRONICS AND POWER DISTRIBUTION
8) ACHIEVED IS FOR SYSTEM WITH POWER GENERATION/POWER CONVERSION
9) ACHIEVED D05685503 IS BASED ON D05685503 FOR ALL EXCEPT POWER. POWER IS BASED ON SECOND SURVEY
10) SPECIFIED AVAILABILITY IS TAC REQUIREMENT FROM ESR REPORT FOR ALL AN/TSC-60(V)
11) ACHIEVED ESR IS FOR ALL TAC AN/TSC-60(V) EQUIPMENTS

3.3.2.7 AN/TSC-60(V)-3 Results

The percent specified (predicted) and achieved MTBF, MTTR and A_a contribution of the power, ECU, power distribution and electronic equipments to the AN/TSC-60(V)-3 system is given below:

D056B5503 REPORT

EQUIPMENT	PERCENT CONTRIBUTION MTBF (1) SPECIFIED	MTBF (1) ACHIEVED	MTTR (2) PREDICTED	MTTR (2) ACHIEVED	A_a PREDICTED	A_a ACHIEVED
WITH POWER GENERATION						
ELECTRONICS	33.9	44.2	13.0	45.7	13.0	45.9
POWER DISTRIBUTION	0.3	0.8	0.1	0.7	2.2	0.7
ECU	36.2	1.6	62.2	1.9	60.9	2.0
POWER GENERATION	29.6	53.4	24.7	51.7	23.9	51.4
WITH POWER CONVERSION						
ELECTRONICS	45.5	89.5	13.0	66.6	13.0	66.0
POWER DISTRIBUTION	0.5	1.7	0.1	0.1	2.2	1.0
ECU	48.7	3.4	62.2	2.7	60.9	2.9
POWER CONVERSION	5.3	5.4	24.7	29.7	23.9	30.1

Notes: 1) Achieved is MTBME
2) Achieved is MMMR

The results indicate the ECU and power distribution equipments do not have an adverse impact on the system R/M. The power generation and power conversion equipments do have an adverse impact.

3.3.2.8 AN/TSQ Analysis

The current Air Force inventory was obtained from the Item Manager at SM-ALC on 10 February 1982. The inventory is for maximum configuration systems and is as follows:

EQUIPMENT	AIR FORCE	TACTICAL AIR COMMAND (TAC)
AN/TSQ-91	16	5
AN/TSQ-92	6	4
AN/TSQ-93	13	4
TOTAL	35	13

The information used to derive the average operating time is given in Table 3.3.2-5. Two averages were calculated. One for TAC units and one for all Air Force units The TAC operating time estimate was derived from the two TAC units. This estimate was used to develop the R/M numerics for the field experience data given for the AN/TSQ-91 TAC BLIS report. The operating time estimates derived from all the Air Force units for the AN/TSQ-91, AN/TSQ-92 and AN/TSQ-93 were used to develop the R/M numerics for the field experience data given in the D056B5503 reports.

Figures 3.3.2-2 through 3.3.2-4 give simplified Reliability Block Diagrams (RBD) and Reliability Mathematical Models (RMM) for the AN/TSQ-91, AN/TSQ-92 and AN/TSQ-93 equipments. The diagrams and models depict a logistics configuration wherein it is assumed that if any equipment fails the system fails. The functional RBD and RMM for the TSQ equipments includes redundant elements and provides a more realistic representation of the system operation success paths. The logistics R/M numerics were used because the data available from the field maintenance reports could be used to generate reasonably accurate comparisons for logistics R/M numerics, but could not be relied upon to provide information on system mission capability. Any mission capability data collected during the study are discussed in the appropriate section.

The specified and predicted R/M numerics for the AN/TSQ systems were extracted from the AAA report (ref 32). These data are listed in Table 3.3.2-6. The system level R/M numerics were calculated based on the data given in Table 3.3.2-6 for the modules and a maximum configuration system which was assumed from the inventory data. The MTBF and Mct specified and predicted estimates for the power distribution and ECU equipments were obtained from reference 32. The M numeric for the AN/TSQ systems was specified as Mct. The M numeric for the power equipments was specified as A_a or MTTR. For consistency Mct was assumed to be equal to MTTR. This assumption does not create any biases if one maintenance person repairs the equipment. The MTBF and MTTR estimates for the power equipment were obtained from data extracted from the equipment specifications or from data extracted from the Initial Production Test (IPT) reports (ref 2, 11, 13, 14, 15). The AN/TSQ systems operate with two different types of power equipment - power generation and power conversion. The MTBF, MTTR and A_a system level estimates were revised utilizing both types of power source. The power

TABLE 3.3.2-5: AN/TSQ OPERATING TIME INFORMATION

AN/TSQ-91

UNIT	HOURS/EQUIPMENT HOME	DEPLOYED	TOTAL	NO EQUIP	TOTAL OP HRS	MODULE TYPE	UNIT TYPE
103 TCS	1512	810	2322	1	2322		ANG
603 TCS	8760	0	8760	1	8760		AF
101 TCS	--	336	336	1	336		ANG
606 TCS	4800	2160	6960	1	6960		AF
609 TCS	3360	1632	4992	1	4992		AF
728 TCS	2400	1680	4080	2	8160		AF TAC
			TOTALS	7	31530		

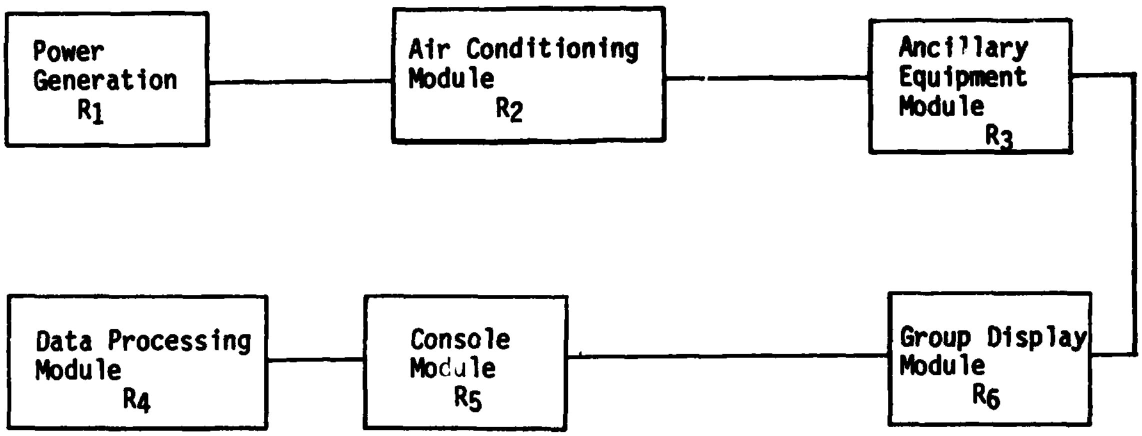
AN/TSQ-92

UNIT	HOURS/EQUIPMENT HOME	DEPLOYED	TOTAL	NO EQUIP	TOTAL OP HRS	MODULE TYPE (1)	UNIT TYPE
105 TCS	720	630	1350	2	2700	TSA-34	ANG
105 TCS	720	630	1350	2	2700	OA`8448	ANG
105 TCS	720	630	1350	1	1350	TSA-35	ANG
			TOTALS	5	6750		

AN/TSQ-93

UNIT	HOURS/EQUIPMENT HOME	DEPLOYED	TOTAL	NO EQUIP	TOTAL OP HRS	MODULE TYPE	UNIT TYPE
604 DASS	3104	432	3536	1	3536		AF
111 CEM SQ	1600	1188	2788	1	2788		ANG
105 CEM	560	2160	2720	1	2720		ANG
			TOTALS	3	9044		

Notes: 1) Data were given for each module type. This is one system.



Power
Distribution
R_7

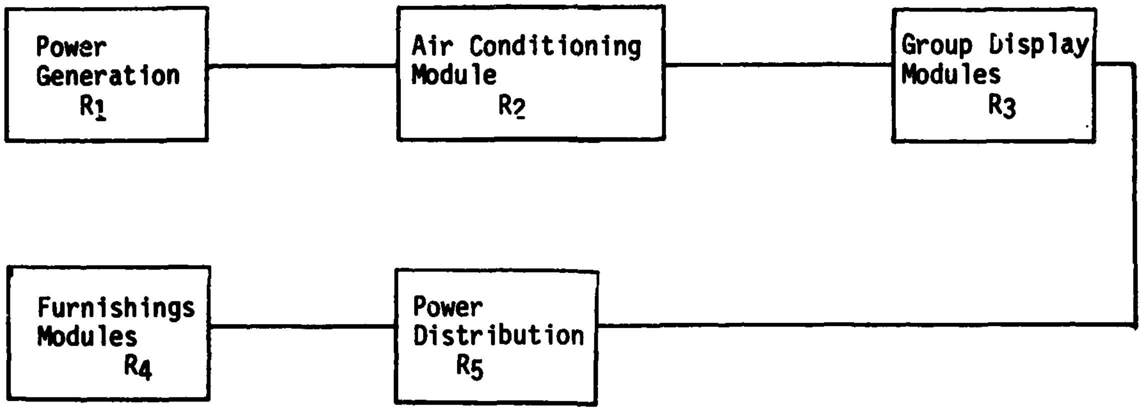
Reliability math Model: $R_{[illegible]} = R_1 R_2 R_3 R_4 R_5 R_6 R_7$

Three configurations of the TSQ-91 vary the reliability block diagram by number of modules:

Type Modules	Minimum	Configuration Intermediate	Maximum
Air Conditioning	1	2	2
Ancillary Equipment	1	1	1
Data Processing	1	1	1
Console	1	2	3
Group Display	1	2	3

Note 1: R_1 and R_2 does not include shelter or pallet, R_3 - R_6 includes shelter. R_7 includes portions of R_1 - R_6.

FIGURE 3.3.2-2: AN/TSQ-91 RELIABILITY BLOCK DIAGRAM AND MATH MODEL



Reliability math Model: $R_S = R_1 R_2 R_3 R_4 R_5$

There are three configurations of the TSQ-92:

Type Modules	Configuration Combat Ops & Plans	Combat Ops	Combat plans
Air Conditioning (1)	1	1	1
Group Display (1)	2	2	2
Furnishings	2	2	2

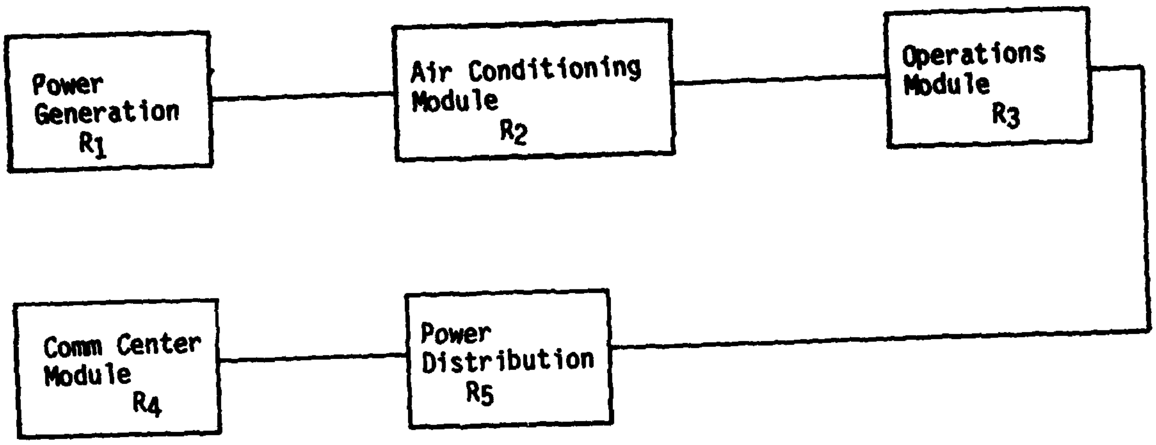
Note 1: Air conditioning and Group Display Modules are interchangeable with TSQ-91

FIGURE 3.3.2-3: AN/TSQ-92 RELIABILITY BLOCK DIAGRAM AND MATH MODEL

AD-A120 360 IIT RESEARCH INST CHICAGO IL F/G 9/1
R/M ANALYSIS OF ELECTROMECHANICAL EQUIPMENTS.(U)
MAY 82 J J STEINKIRCHNER F30602-81-C-0046
UNCLASSIFIED RADC-TR-82-141 NL

2 of 2

END
DATE FILMED
11 82



Reliability math Model: $R_S = R_1 R_2 R_3 R_4 R_5$

Three configurations vary the reliability block diagram by number of modules:

Type Modules	Alternate	Configuration Minimum	Medium
Air Conditioning	1	2	3
Operations	1	1	2
Comm Center	0	1	1

FIGURE 3.3.2-4: AN/TSQ-93 RELIABILITY BLOCK DIAGRAM AND MATH MODEL

TABLE 3.3.2-6: AN/TSQ R/M NUMERICS

EQUIPMENT	MTBF (HOURS)			Mct (HOURS)			AVAILABILITY	
	SPECIFIED	MINIMUM ACCEPTABLE	PREDICTED (5)	SPECIFIED	MAXIMUM ACCEPTABLE	PREDICTED	MINIMUM ACCEPTABLE	PREDICTED
AN/TSQ-91 (MAXIMUM)	170	85	190(1)	0.65	1.46	0.51	0.980	0.9919
AN/TSQ-92 (MAXIMUM)	250(2)	125	250(1)		2.00(3)	1.01	0.988	0.9999
AN/TSQ-93 (MEDIUM)	250(2)	125	250(1)		2.00(3)	0.97	0.988	0.9950
DATA PROCESSING	201	100(2)	122/63.4		0.65	0.43		
CONSOLE	192(2)	95.9	169	1.30		0.69		
ANCILLARY EQUIPMENT	158(2)	79.2	101	1.25		0.97		
FURNISHINGS	336(2)	118	118		1.30	1.12		
GROUP DISPLAY	400(2)	200	671		0.50	0.52		
A/C TSQ-91 & TSQ-92	500	250(2)	--		3.40	2.00		
A/C TSQ-93	502(2)	251	--		3.50	1.73		
OPERATIONS	141(2)	70.6	378		1.40	0.43	1.10	1.07
COMMUNICATIONS	238(2)	119		119				
OPERATIONS HEATER			2000(1)	2000				2.00
COMMUNICATIONS HEATER			2000(1)	2000				2.00
DATA PROCESSING PDN			16500(1)	8865				1.47
CONSOLE PDN			102000(1)	55249				1.47
ANCILLARY EQUIPMENT PDN			18600(1)	10081				1.47
GROUP DISPLAY PDN			170000(1)	91743				1.47

NOTES:

1) ALLOCATED NUMERIC
2) BASED ON 2:1 DISCRIMINATION RATIO
3) 0.9 Mmax VALUE
4) FUNCTIONAL/LOGISTICS MTBF

equipment R/M numerics are averages of the types used with the system and were obtained by calculating the R/M numerics from the data obtained during the second survey. The AN/TSQ systems utilize the A/E24U-8, EMU-12, EMU-21, EMU-22 and MB-15, for power generation and MD-4 for power conversion. The R/M numerics for the power equipments used with the AN/TSQ equipments are:

			R/M NUMERIC					
			MTBF		MTTR		A_a	
EQUIPMENT	TYPE	QTY	SPEC	ACHIEVED	SPEC	ACHIEVED	SPEC	ACHIEVED
POWER GENERATION	MB-15	23	1000	35.5	2.0	4.2	--	0.8942
	EMU-30	134	500	167	--	6.3		0.9636
	Total	157	540	108	2.0	6.0	0.90	0.9474
POWER CONVERSION	MD-4		4000	1745	0.5	44.7	0.90	0.9750

3.3.2.9 AN/TSQ-91 Analysis

The field experience data summarized from the TAC BLIS report are given below. This data covers the twelve month calendar period August 1980 to August 1981 for five AN/TSQ-91 systems.

CHARACTERISTIC	SYSTEM	ELECTRONIC EQUIPMENT	POWER DISTRIBUTION	ECU
Total Maintenance Events	439	408	5	26
Total Maintenance Actions	732	661	5	57
Maintenance Events with System Downtime	30	29	0	1
Total Maintenance Manhours	2516.9	2286.8	17.6	212.5
Maintenance Manhours with System Down time	646.9	646.4	0	0.5
Average Operate hours/year	4080	4080	4080	4080
Total operate hours/year	20400	20400	20400	20400
Mean Time Between Maintenance Events (MTBME) (Hours)	46.5	50.0	4080	785
Mean Time Between System Downtime	680	730	--	20400

The power distribution network was defined as WUCs ABAAO, ABABO, ABACO, ACAGO, ACDCO, ADAFO, ADEAO, ADEBO, ADEDO, ADEEO, AERBO and AERAO.

As can be seen by the data presented above there is an average of 1.65 maintenance actions for each maintenance event. This is one reason why it is imperative that maintenance events be identified and used to assess the achieved R/M rather than the number of maintenance actions. It can also be seen that only 6.8% of the maintenance events resulted in system downtime; therefore, MTBME should not be used to assess the achieved mission reliability unless the events can be further qualified to determine if system downtime resulted from the event. The power distribution equipment did not cause any system downtime during this reporting period and only one of the ECU failures (3.8%) resulted in system downtime.

The field experience data summarized from the D056B5503 report is given below. This data covers a twelve month reporting period for sixteen (16) AN/TSQ-91 equipments.

CHARACTERISTIC	*SYSTEM*	*ELECTRONIC* EQUIPMENT	*POWER* DISTRIBUTION	*ECU*
FAILURES	2413	2222	43	148
OTHER MALFUNCTIONS	170	159	8	3
NO DEFECT	0	0	0	0
TOTAL EVENTS	2583	2381	51	151
MAINTENANCE MAN HOURS	8263.4	6779.8	233.8	1249.8
AVERAGE OPHRS/YEAR	4080	4080	4080	4080
TOTAL OPERATE HOURS	65280	65280	65280	65280
TOTAL POSSESSION HOURS	140160	140160	140160	140160

As can be seen by the data presented above 93% of field maintenance actions are classifed as failures.

The data used for the percentage calculations are presented in Table 3.3.2-7.

TABLE 3.3.2-7: AN/TSQ-91 R/M NUMERICS

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	2ND SURVEY	TAC BLIS	D056B5503	NOTES
SYSTEM	MTBM (OPERATE HOURS)							
	POINTS ESTIMATE	23.7/25.7	17.0			22.7/44.1	16.1/24.5	5, 6, 9, 10, 11, 12, 13, 15
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					19.8/38.9	14.7/23.2	11, 12, 13
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					26.0/49.8	17.6/26.0	11, 12, 13
	SINGLE-SIDED 90% CONFIDENCE LIMIT					20.4/39.9	15.0/23.5	11, 12, 13
	SINGLE-SIDED 60% CONFIDENCE LIMIT							
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE					93.1/93.4	52.3/52.4	11, 12, 13
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					83.6/82.0	49.8/49.3	11, 12, 13
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					104/106	54.9/55.4	11, 12, 13
	SINGLE-SIDED 90% CONFIDENCE LIMIT					85.7/84.5	50.3/49.9	
	MTTR		0.9			5.7/7.7	4.1/4.3	9, 10, 11, 12, 13
	AVAILABILITY (Aa)		0.9459			0.7880/0.8458	0.7860/0.8437	9, 10, 11, 12, 13, 14, 15
ELECTRONICS	MTBM (OPERATE HOURS)							
	POINT ESTIMATE	29.0	20.9			50	27.4	1, 15
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					46.2	26.5	
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					54.3	28.4	
	SINGLE-SIDED 90% CONFIDENCE LIMIT					46.9	26.7	
	SINGLE-SIDED 60% CONFIDENCE LIMIT							
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE					107	58.9	
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					99.2	56.9	
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					117	60.9	
	SINGLE-SIDED 90% CONFIDENCE LIMIT					101	57.3	
	MTTR		0.6			5.6	2.8	
	AVAILABILITY (Aa)		0.9698			0.8993	0.9073	

TABLE 3.3.2-7: AN/TSQ-91 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	2ND SURVEY	TAC BLIS	D056B5503	NOTES
POWER DISTRIBUTION	MTBM (OPERATE HOURS)							
	POINT ESTIMATE	6195	3344			4080	1280	1
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					1940	1014	
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					10355	1638	
	SINGLE-SIDED 90% CONFIDENCE LIMIT					2199	1063	
	SINGLE-SIDED 60% CONFIDENCE LIMIT							
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE					8760	2748	
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					4165	2176	
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					22234	3517	
	SINGLE-SIDED 90% CONFIDENCE LIMIT					4722	2282	
	SINGLE-SIDED 60% CONFIDENCE LIMIT							
	MTTR		1.5			3.5	4.6	
	AVAILABILITY (Aa)		0.9996			0.9991	0.9964	
ECU	MTBM (OPERATE HOURS)							
	POINT ESTIMATE	250		111	220	785	432	2, 16, 18, 20
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			85	175	565	378	2, 16, 18
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			146	279	1120	497	2, 16, 18
	SINGLE-SIDED 90% CONFIDENCE LIMIT			90	194	603	388	2, 6, 16, 18
	SINGLE-SIDED 60% CONFIDENCE LIMIT			66				2, 16, 18
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE			834	1162	1685	928	2, 16, 18
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			643	926	1214	811	2, 16, 18
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			1100	1476	2404	1067	2, 16, 18
	SINGLE-SIDED 90% CONFIDENCE LIMIT					1294	834	2, 16, 18
	SINGLE-SIDED 60% CONFIDENCE LIMIT							
	MTTR (SPECIFIED)		2.0	2.5	4.5	8.2	8.3	2
	(MAX ACCEPTABLE)	3.4						
	AVAILABILITY (Aa)	0.9866		0.9780	0.9799	0.9897	0.9811	

TABLE 3.3.2-7: AN/TSQ-91 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	2ND SURVEY	TAC BLIS	D05685503	NOTES
POWER GENERATION	MTBM (OPERATE HOURS)							
	POINT ESTIMATE	265		610/111	44.4			2, 4, 6, 8, 17, 19, 20
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			239/91.0	37.7			2, 8, 17, 19
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			1227/145	52.5			2, 8, 17, 19
	SINGLE-SIDED 90% CONFIDENCE LIMIT			371/87.0	39.0			2, 8, 17, 19
	SINGLE-SIDED 60% CONFIDENCE LIMIT							
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE			3068	1450			2, 17, 19
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			1700	1230			2, 17, 19
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			6166	1720			2, 17, 19
	SINGLE-SIDED 90% CONFIDENCE LIMIT				1273			2, 17, 19
	MTTR (CLOCK-HOURS)	2.0		1.4	5.7			2
	(MAN HOURS)			1.8				2
	AVAILABILITY (Aa)	0.9925		0.9977	0.8862			2
POWER CONVERSION	MTBM (OPERATE HOURS)							
	POINT ESTIMATE	2000/200		610/111	872			2, 6, 7, 8, 17, 19, 20
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			338/91	558			2, 8, 17, 19
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			1227/145	1444			2, 8, 17, 19
	SINGLE-SIDED 90% CONFIDENCE LIMIT			376/82	607			2, 8, 17, 19
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE			3068	1526			2, 17, 19
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			1700	976			2, 17, 19
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			6166	2525			2, 17, 19
	SINGLE-SIDED 90% CONFIDENCE LIMIT				1061			2, 17, 19
	MTTR (CLOCK-HOURS)	0.5		1.4	44.7			2
	(MAN HOURS)	1.0		1.8				2
	AVAILABILITY (Aa)	0.9998		0.9977	0.9512			2

TABLE 3.3.2-7: AN/TSQ-91 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	2ND SURVEY	TAC BLIS	D056B5503	NOTES

NOTES:

1) SPECIFIED IS AN ALLOCATED NUMERIC
2) DEMONSTRATED IS AN AVERAGE FROM IPT EQUIPMENTS
3) IPT REQUIREMENT
4) SPECIFIED IS A WEIGHTED AVERAGE
5) SPECIFIED INCLUDES ECU & POWER GENERATION/ECU & POWER CONVERSION SPECIFIED NUMERICS
6) SPECIFIED IS MTBF
7) SPECIFIED IS MTBF/MTBM
8) DEMONSTRATED IS AN AVERAGE FROM IPT EQUIPMENTS BASED ON CHARGEABLE FAILURES/ALL MALFUNCTIONS
9) DEMONSTRATE IS BASED ON DEMONSTRATED NUMERICS FOR THE SEPARATE EQUIPMENTS. NO SYSTEM LEVEL TEST DATA WERE AVAILABLE.
10) PREDICTED IS BASED ON DEMONSTRATED NUMERICS FOR THE ECU AND POWER EQUIPMENTS AND PREDICTED NUMERICS FOR THE ELECTRONICS AND POWER DISTRIBUTION
11) ACHIEVED TAC BLIS IS BASED ON TAC BLIS FOR ALL EXCEPT POWER. POWER IS BASED ON SECOND SURVEY
12) ACHIEVED IS FOR SYSTEM WITH POWER GENERATION/POWER CONVERSION
13) ACHIEVED D056B5503 IS BASED ON D056B5503 FOR ALL EXCEPT POWER. POWER IS BASED ON SECOND SURVEY
14) SPECIFIED AVAILABILITY IS TAC REQUIREMENT FROM ESR REPORT FOR ALL AN/TSC-60(V)
15) ALLOCATED BASED ON MAXIMUM CONFIGURATION SYSTEM
16) THE IPT DEMONSTRATION MTBM NUMERICS WERE DIVIDED BY EIGHT TO SIMULATE 8 SERIES UNITS.
17) THE IPT DEMONSTRATION MTBM NUMERICS WERE DIVIDED BY TWO TO SIMULATE 2 SERIES UNITS.
18) THE SECOND SURVEY MTBM DATA WERE DIVIDED BY EIGHT TO SIMULATE 8 SERIES UNITS.
19) THE SECOND SURVEY MTBM DATA WERE DIVIDED BY TWO TO SIMULATE 2 SERIES UNITS.
20) THE SPECIFIED MTBM DATA WERE DIVIDED BY TWO TO SIMULATE 2 SERIES UNITS.

The system, ECU, Electronics and power R/M numerics are based on the following equipment quantities:

EQUIPMENT	QUANITITY
AIR CONDITIONING (ACM)	2
ANCILLARY EQUIPMENT (AEM)	1
DATA PROCESSING (DPM)	1
CONSOLE (CM)	3
GROUP DISPLAY (GDM)	3
POWER	2

These estimates are based on a maximum configuration system. The system level specified MTBF is given then by:

$$\frac{1}{\mathrm{MTBF(System)}} = \frac{2}{\mathrm{MTBF(ACM)}} + \frac{1}{\mathrm{MTBF(AEM)}} + \frac{1}{\mathrm{MTBF(DPM)}} + \frac{3}{\mathrm{MTBF(CM)}} + \frac{3}{\mathrm{MTBF(GDM)}} + \frac{2}{\mathrm{MTBF(Power)}}$$

The ECU, Electronics, Power Distribution Network and Power equipment specified MTBF is equal to the MTBF of the equipment divided by the quantity used. Each ACM has four A/Cs; therefore the IPT and second survey achieved ECU MTBMs were divided by four to obtain an MTBM equivalent to the ACM.

The system and electronic equipment specified MTTR is a weighted average derived by the equation:

$$\mathrm{MTTR\ (S)} = \frac{\sum_{i=1}^{n} ((\text{Failure rate})_i \times (\text{Mct})_i \times \text{QTY}_i)}{\sum_{i=1}^{n} ((\text{Failure rate})_i \times \text{QTY}_i)}$$

3.3.2.10 AN/TSQ-91 Results

The percent specified (predicted) and achieved MTBM, MTTR and A_a contribution of the power, ECU, power distribution and electronic equipments to the AN/TSQ-91 system is given below for the three report types:

TAC BLIS REPORT

EQUIPMENT	PERCENT CONTRIBUTION MTBF (1) SPECIFIED	MTBF (1) ACHIEVED	MTTR (2) PREDICTED	MTTR (2) ACHIEVED	A_a PREDICTED	A_a ACHIEVED
WITH POWER GENERATION						
ELECTRONICS	81.4	45.4	53.3	44.5	55.2	44.6
POWER DISTRIBUTION	0.4	0.6	0.8	0.3	0.7	0.4
ECU	9.4	2.9	41.7	4.2	40.0	4.3
POWER GENERATION	8.8	51.1	4.2	51.0	4.1	50.7
WITH POWER CONVERSION						
ELECTRONICS	88.1	88.2	53.3	64.1	55.2	63.4
POWER DISTRIBUTION	0.4	1.1	0.8	0.5	0.7	0.5
ECU	10.2	5.6	41.7	6.0	40.0	6.2
POWER CONVERSION	1.3	5.1	4.2	29.4	4.1	29.9

Notes: 1) Achieved is MTBME
2) Achieved is MMMR

D056B5503 REPORT

EQUIPMENT	PERCENT CONTRIBUTION MTBF (1) SPECIFIED	MTBF (1) ACHIEVED	MTTR (2) PREDICTED	MTTR (2) ACHIEVED	A_a PREDICTED	A_a ACHIEVED
WITH POWER GENERATION						
ELECTRONICS	81.4	58.8	53.3	40.4	55.2	40.4
POWER DISTRIBUTION	0.4	1.2	0.8	1.4	0.7	1.5
ECU	9.4	3.7	41.7	7.5	40.0	7.9
POWER GENERATION	8.8	36.3	4.2	50.7	4.1	50.2
WITH POWER CONVERSION						
ELECTRONICS	88.1	89.6	53.3	58.0	55.2	57.3
POWER DISTRIBUTION	0.4	1.9	0.8	2.0	0.7	2.1
ECU	10.2	5.7	41.7	10.9	40.0	11.2
POWER CONVERSION	1.3	2.8	4.2	29.1	4.1	29.4

Notes: 1) Achieved is MTBME
2) Achieved is MMMR

The results indicate that the ECU and power distribution equipments do not have an adverse impact on the system R/M, but that the power generation and power conversion equipments do have an adverse impact. These results were obtained from both the TAC BLIS and the D056B5503 reports. Since none of the power distribution equipment failures resulted in system downtime, the failures had no impact on the system functional reliability; also, since only one of the ECU failures resulted in system downtime, the ECU equipment has a small impact on system functional reliability (one failure every five calendar year).

ESR REPORT (AVAILABILITY)

	SPECIFIED	TAC STANDARD	ACHIEVED
TSQ-91	0.893	0.95	0.878

3.3.2.11 AN/TSQ-92 Analysis

The field experience data summarized from the D056B5503 report is given below. This data covers a twelve month reporting period for six (6) AN/TSQ-92 equipments.

CHARACTERISTIC	SYSTEM	ELECTRONIC EQUIPMENT	POWER DISTRIBUTION	ECU
FAILURES	61	57	0	4
OTHER MALFUNCTIONS	9	9	0	0
NO DEFECT	0	0	0	0
TOTAL EVENTS	70	66	0	4
MAINTENANCE MAN HOURS	82.3	60.6	0	21.7
AVERAGE OPHRS/YEAR	1350	1350	1350	1350
TOTAL OPERATE HOURS	8100	8100	8100	8100
TOTAL POSSESSION HOURS	52560	52560	52560	52560

The power distribution network definition used for the AN/TSQ-92 is the same as was used for the AN/TSQ-91.

As can be seen by the data presented above 87.1% of field maintenance actions are failures.

The AN/TSQ-92 field experience data used for the percentage calculations are presented in Table 3.3.2-8. The specified, predicted and demonstrated R/M numerics for the power equipment are presented in Table 3.3.2-7.

The system, ECU, Electronics and power R/M numerics are based on the following equipment quantities:

EQUIPMENT	QUANITITY
AIR CONDITIONING (ACM)	1
FURNISHINGS (FM)	2
GROUP DISPLAY (GDM)	2
POWER	2

These estimates are based on a maximum configuration system. The system level specified MTBF is given then by:

$$\frac{1}{\text{MTBF(System)}} = \frac{1}{\text{MTBF(ACM)}} + \frac{2}{\text{MTBF(FM)}} + \frac{2}{\text{MTBF(GDM)}} + \frac{2}{\text{MTBF(Power)}}$$

The ECU, Electronics, Power Distribution Network and Power equipment specified MTBF is equal to the MTBF of the equipment divided by the quantity used. Each ACM has four A/Cs; therefore the IPT and second survey achieved MTBMs were divided by four to obtain an MTBM equivalent to the ACM.

The system and electronic equipment specified MTTR is a weighted average derived by the equation:

$$\text{MTTR (S)} = \frac{\sum_{i=1}^{n} ((\text{Failure rate})_i \text{ X } (\text{Mct})_i \text{ X } \text{QTY}_i)}{\sum_{i=1}^{n} ((\text{Failure rate})_i \text{ X } \text{QTY}_i)}$$

TABLE 3.3.2-8: AN/TSQ-92 R/M NUMERICS

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	D056B5503	NOTES
SYSTEM	MTBM (OPERATE HOURS)					
	POINT ESTIMATE	59.8/74.3	38.3		32.1/102	4, 5, 6, 7, 8, 9
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				26.6/77.4	8, 9
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				38.8/134	8, 9
	SINGLE-SIDED 90% CONFIDENCE LIMIT				27.6/81.6	8, 9
	SINGLE-SIDED 60% CONFIDENCE LIMIT					
	MTBM (POSSESSED HOURS)					
	POINT ESTIMATE				494/503	8, 9
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				396/365	8, 9
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				617/697	8, 9
	SINGLE-SIDED 90% CONFIDENCE LIMIT				414/389	
	MTTR (SPECIFIED)		1.3		4.4/6.2	6, 7, 8, 9
	AVAILABILITY (Aa)		0.9672		0.8774/0.9417	6, 7, 8, 9, 10, 11,
ELECTRONICS	MTBM (OPERATE HOURS)					
	POINT ESTIMATE	91.3	50.2		123	1, 6
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				100	
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				152	
	SINGLE-SIDED 90% CONFIDENCE LIMIT				104	
	SINGLE-SIDED 60% CONFIDENCE LIMIT					
	MTBM (POSSESSED HOURS)					
	POINT ESTIMATE				796	
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				649	
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				987	
	SINGLE-SIDED 90% CONFIDENCE LIMIT				677	
	MTTR (SPECIFIED)		1.0		0.9	
	AVAILABILITY (Aa)		0.9805		0.9927	

TABLE 3.3.2-8: AN/TSQ-92 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	D05685503	NOTES
POWER DISTRI-BUTION	MTBM (OPERATE HOURS)					
	POINT ESTIMATE	85000	45872			1, 5
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					
	SINGLE-SIDED 90% CONFIDENCE LIMIT					
	SINGLE-SIDED 60% CONFIDENCE LIMIT				8785	
	MTBM (POSSESSED HOURS)					
	POINT ESTIMATE					
	LOWER 90% CONFIDENCE INTERVAL-LIMIT					
	UPPER 90% CONFIDENCE INTERVAL-LIMIT					
	SINGLE-SIDED 90% CONFIDENCE LIMIT					
	SINGLE-SIDED 60% CONFIDENCE LIMIT				57006	
	MTTR (SPECIFIED)		1.5		0.0	
	AVAILABILITY (Aa)		0.9999		1.0000	
ECU	MTBM (OPERATE HOURS)					
	POINT ESTIMATE	500		221	2025	2, 10
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			170	885	2, 10
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			292	5934	2, 10
	SINGLE-SIDED 90% CONFIDENCE LIMIT			180	1013	2, 5, 10
	SINGLE-SIDED 60% CONFIDENCE LIMIT					
	MTBM (POSSESSED HOURS)					
	POINT ESTIMATE			1668	13140	2, 10
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			1285	5741	2, 10
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			2201	38505	2, 10
	SINGLE-SIDED 90% CONFIDENCE LIMIT				6574	2
	SINGLE-SIDED 60% CONFIDENCE LIMIT					
	MTTR (CLOCK-HOURS)			2.5	5.4	2
	(MAN HOURS)					
	AVAILABILITY (Aa)			0.9888	0.9973	

TABLE 3.3.2-8: AN/TSQ-92 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	D05685503	NOTES

NOTES:

1) SPECIFIED IS AN ALLOCATED NUMERIC
2) DEMONSTRATED IS AN AVERAGE FROM IPT EQUIPMENTS
3) SPECIFIED IS A WEIGHTED AVERAGE
4) SPECIFIED INCLUDES ECU & POWER GENERATION/ECU & POWER CONVERSION SPECIFIED NUMERICS
5) SPECIFIED IS MTBF
6) DEMONSTRATE IS BASED ON DEMONSTRATED NUMERICS FOR THE SEPARATE EQUIPMENTS. NO SYSTEM LEVEL TEST DATA WERE AVAILABLE.
7) PREDICTED IS BASED ON DEMONSTRATED NUMERICS FOR THE ECU AND POWER EQUIPMENTS AND PREDICTED NUMERICS FOR THE ELECTRONICS AND POWER DISTRIBUTION
8) ACHIEVED IS FOR SYSTEM WITH POWER GENERATION/POWER CONVERSION
9) ACHIEVED D05685503 IS BASED ON D05685503 FOR ALL EXCEPT POWER. POWER IS BASED ON SECOND SURVEY
10) THE DEMONSTRATED IPT MTBM DATA WERE DIVIDED BY FOUR TO SIMULATE 4 SERIES UNITS

3.3.2.12 AN/TSQ-92 Results

The percent specified (predicted) and achieved MTBF, MTTR and A_a contribution of the power, ECU, power distribution and electronic equipments to the AN/TSQ-92 system is given below:

D056B5503 REPORT

EQUIPMENT	PERCENT CONTRIBUTION MTBF (1)		MTTR (2)		A_a	
	SPECIFIED	ACHIEVED	PREDICTED	ACHIEVED	PREDICTED	ACHIEVED
WITH POWER GENERATION						
ELECTRONICS	65.3	26.0	59.4	5.3	59.0	5.6
POWER DISTRIBUTION	0.1	0.4	0.1	0.0	0.3	0.0
ECU	12.0	1.6	33.7	1.9	33.8	2.1
POWER GENERATION	22.6	72.0	6.8	92.8	6.9	92.3
WITH POWER CONVERSION						
ELECTRONICS	31.3	82.1	59.4	12.0	59.0	12.2
POWER DISTRIBUTION	0.3	1.2	0.1	0.1	0.3	0.0
ECU	14.9	5.0	33.7	4.4	33.8	4.5
POWER CONVERSION	3.7	11.7	6.8	83.6	6.9	83.3

Notes: 1) Achieved is MTBME
2) Achieved is MMMR

ESR REPORT (AVAILABILITY)

	SPECIFIED	TAC STANDARD	ACHIEVED
TSQ-92	0.958	0.95	0.958

The results indicate that the ECU and power distribution equipments do not have an adverse impact on the system R/M. The power generation and power conversion equipments do have an adverse impact. The power distribution equipment achieved MTBM percentage was higher than what was predicted; however, this was due to the fact that zero failures occurred.

3.3.2.13 AN/TSQ-93 Analysis

The field experience data summarized from the D056B5503 report are given below. This data covers a twelve month reporting period for thirteen (13) AN/TSQ-93 equipments.

CHARACTERISTIC	SYSTEM	ELECTRONIC EQUIPMENT	POWER DISTRIBUTION	ECU
FAILURES	332	316	3	13
OTHER MALFUNCTIONS	208	200	1	7
NO DEFECT	0	0	0	0
TOTAL EVENTS	540	516	4	20
MAINTENANCE MAN HOURS	890.9	816.9	6.5	67.6
AVERAGE OPHRS/YEAR	3014.7	3014.7	3014.7	3014.7
TOTAL OPERATE HOURS	39191	39191	39191	39191
TOTAL POSSESSION HOURS	113880	113880	113880	113880

The power distribution network was defined as WUCs AAAA0, AAAB0, AAAC0, and ABAB0.

As can be seen by the data presented above 61.5% of field maintenance actions are failures.

The AN/TSQ-93 field experience data used for the percentage calculations are presented in Table 3.3.2-9. The specified, predicted and demonstrated R/M numerics for the power equipment are presented in Table 3.3.2-7.

The system, ECU, Electronics and power R/M numerics are based on the following equipment quantities:

EQUIPMENT	QUANITITY
AIR CONDITIONING (ACM)	3
COMMUNICATIONS MODULES (CM)	1
OPERATIONS MODULE (OM)	2
POWER	2

TABLE 3.3.2-9: AN/TSQ-93 R/M NUMERICS

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	D05685503	NOTES
SYSTEM	MTBM (OPERATE HOURS)					
	POINT ESTIMATE	35.5/40.2	53.4		27.6/67.0	4, 5, 6, 7, 8, 9
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				24.0/59.1	8, 9
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				31.6/75.2	8, 9
	SINGLE-SIDED 90% CONFIDENCE LIMIT				24.7/64.0	8, 9
	SINGLE-SIDED 60% CONFIDENCE LIMIT					
	MTBM (POSSESSED HOURS)					
	POINT ESTIMATE				184/185	8, 9
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				168/162	8, 9
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				201/208	8, 9
	SINGLE-SIDED 90% CONFIDENCE LIMIT				169/165	
	MTTR (SPECIFIED)		1.2		4.2/5.0	6, 7
	AVAILABILITY (Aa)		0.9780		0.8663/0.9298	6, 7, 8, 9, 10, 11,
ELECTRONICS	MTBM (OPERATE HOURS)					
	POINT ESTIMATE	54.4	73.0		76.0	1, 6
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				70.6	
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				81.8	
	SINGLE-SIDED 90% CONFIDENCE LIMIT				71.7	
	SINGLE-SIDED 60% CONFIDENCE LIMIT					
	MTBM (POSSESSED HOURS)					
	POINT ESTIMATE				221	
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				205	
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				238	
	SINGLE-SIDED 90% CONFIDENCE LIMIT				208	
	MTTR (SPECIFIED)		0.8		1.6	
	AVAILABILITY (Aa)		0.9892		0.9794	

TABLE 3.3.2-9: AN/TSQ-93 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	D056B5503	NOTES
POWER DISTRIBUTION	MTBM (OPERATE HOURS)					
	POINT ESTIMATE				9798	1, 5
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				4281	
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				28711	
	SINGLE-SIDED 90% CONFIDENCE LIMIT				4902	
	SINGLE-SIDED 60% CONFIDENCE LIMIT					
	MTBM (POSSESSED HOURS)					
	POINT ESTIMATE				28470	
	LOWER 90% CONFIDENCE INTERVAL-LIMIT				83428	
	UPPER 90% CONFIDENCE INTERVAL-LIMIT				12439	
	SINGLE-SIDED 90% CONFIDENCE LIMIT				14244	
	SINGLE-SIDED 60% CONFIDENCE LIMIT					
	MTTR (SPECIFIED)				1.6	
	AVAILABILITY (Aa)				0.9998	
ECU	MTBM (OPERATE HOURS)					
	POINT ESTIMATE	167		295	1960	2
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			227	1349	2
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			390	2957	2
	SINGLE-SIDED 90% CONFIDENCE LIMIT			240	1449	2, 5
	SINGLE-SIDED 60% CONFIDENCE LIMIT					2
	MTBM (POSSESSED HOURS)					
	POINT ESTIMATE			2223	5694	2
	LOWER 90% CONFIDENCE INTERVAL-LIMIT			1714	3919	2
	UPPER 90% CONFIDENCE INTERVAL-LIMIT			2934	8591	2
	SINGLE-SIDED 90% CONFIDENCE LIMIT				4211	2
	SINGLE-SIDED 60% CONFIDENCE LIMIT					
	MTTR (SPECIFIED)			2.5	3.4	2
	AVAILABILITY (Aa)			0.9916	0.9983	

TABLE 3.3.2-9: AN/TSQ-93 R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	SPECIFIED	PREDICTED	DEMONSTRATION	D05685503	NOTES

NOTES:

1) SPECIFIED IS AN ALLOCATED NUMERIC
2) DEMONSTRATED IS AN AVERAGE FROM IPT EQUIPMENTS
3) SPECIFIED IS A WEIGHTED AVERAGE
4) SPECIFIED INCLUDES ECU & POWER GENERATION/ECU & POWER CONVERSION SPECIFIED NUMERICS
5) SPECIFIED IS MTBF
6) DEMONSTRATE IS BASED ON DEMONSTRATED NUMERICS FOR THE SEPARATE EQUIPMENTS. NO SYSTEM LEVEL TEST DATA WERE AVAILABLE.
7) PREDICTED IS BASED ON DEMONSTRATED NUMERICS FOR THE ECU AND POWER EQUIPMENTS AND PREDICTED NUMERICS FOR THE ELECTRONICS AND POWER DISTRIBUTION
8) ACHIEVED IS FOR SYSTEM WITH POWER GENERATION/POWER CONVERSION
9) ACHIEVED D05685503 IS BASED ON D05685503 FOR ALL EXCEPT POWER. POWER IS BASED ON SECOND SURVEY
10) THE DEMONSTRATED IPT MTBM DATA WERE DIVIDED BY THREE TO SIMULATE 3 SERIES UNITS

These estimates are based on a maximum configuration system. The system level specified MTBF is given then by:

$$\frac{1}{MTBF(System)} = \frac{3}{MTBF(ACM)} + \frac{1}{MTBF(CM)} + \frac{2}{MTBF(OM)} + \frac{2}{MTBF(Power)}$$

The ECU, Electronics, Power Distribution Network and Power equipment specified MTBF is equal to the MTBF of the equipment divided by the quantity used. Each ACM has one A/C; therefore, the IPT and second survey achieved MTBMs were used to obtain an MTBM equivalent to the ACM.

The system and electronic equipment specified MTTR is a weighted average derived by the equation:

$$MTTR\ (S) = \frac{\sum_{i=1}^{n} ((\text{Failure rate})_i \times (\text{Mct})_i \times QTY_i)}{\sum_{i=1}^{n} ((\text{Failure rate})_i \times QTY_i)}$$

3.3.2.14 AN/TSQ-93 Results

The percent specified (predicted) and achieved MTBF, MTTR and A_a contribution of the power, ECU, power distribution and electronic equipments to the AN/TSQ-93 system is given below:

D056B5503 REPORT

EQUIPMENT	PERCENT CONTRIBUTION					
	MTBF (1)		MTTR (2)		A_a	
	SPECIFIED	ACHIEVED	PREDICTED	ACHIEVED	PREDICTED	ACHIEVED
WITH POWER GENERATION						
ELECTRONICS	65.4	36.3	50.4	13.8	50.3	14.5
POWER DISTRIBUTION	0.0	0.3	0.0	0.1	0.0	0.1
ECU	21.2	1.4	38.9	1.1	39.0	1.2
POWER GENERATION	13.4	62.0	10.7	85.0	10.7	84.2
WITH POWER CONVERSION						
ELECTRONICS	73.9	88.2	50.4	28.3	50.3	28.6
POWER DISTRIBUTION	0.0	0.7	0.0	0.2	0.0	0.3
ECU	24.1	3.4	38.9	2.3	39.0	2.3
POWER CONVERSION	2.0	7.7	10.7	69.2	10.7	68.8

Notes: 1) Achieved is MTBME
2) Achieved is MMMR

The results indicate that the ECU and power distribution equipments do not have an adverse impact on the system R/M. The power generation and power conversion equipments do have an adverse impact.

3.3.3 Airborne Tactical C^3I System

The airborne tactical C^3I system selected for analysis was the E-3A AWACS. The E-3A Aircraft is by far the most sophisticated system studied in this report. The first aircraft was delivered to the Air Force in 1973 and the inventory has been steadily increasing with the 25th aircraft being delivered in late 1981. All the Aircraft are assigned to Tinker AFB, OK. The E-3A project has received a great deal of publicity because of the unique capabilities of the aircraft. However, the E-3A was primarily an off-the-shelf system utilizing a Boeing 707 airframe modified with a rotating radar dome mounted on the aircraft's fuselage over the wings. The AWACS Mission systems, for the most part, are operationally ground proven equipment which have been adapted for use in an aircraft. What makes the E-3A AWACS unique is that it can control Tactical Air Operation anywhere in the world without requiring ground support in or near enemy territory. This allows Tactical Air Forces to engage the enemy under radar guidance anytime it is advantageous.

Public interest in the E-3A caused problems during the data collection because the 552 AWACS Wing had numerous information requests on the system. This has caused delays in processing and in some cases rejection of data requests made for this report. Despite these problems, more data were acquired on the E-3A than any of the other systems studied. The data are also higher quality because of the command interest in this high cost system and because of the safety requirement that demands that high quality maintenance and accurate record keeping be maintained on all aircraft. Flying time is also recorded for each aircraft and gives a measure of operating time. Flying time can be multiplied by a factor to obtain ground operating time due to maintenance, training and checkout (maintenance, preflight, postflight, etc.) for the aircraft. The factor for the E-3A, estimated by E-3A maintenance personnel at Tinker AFB, is three. The significance of maintenance operating time is that an estimated 80% of the total KW HR consumed by the E-3A is produced by MEP-116A generators on the ground.

The large amount of ground operating time associated with all aircraft creates a need for efficient less-expensive ground support equipment (SE) to take the place of airborne systems while maintenance is being performed. The ability of the SE to support the aircraft has a definite impact on the availability and maintainability of the system. For this reason and for the obvious importance of reliable performance during flight, this study will consider the E-3A ancillary E/M equipment both inflight and on the ground. The E-3A AWACS inflight ancillary E/M equipment for this report are the aircraft electrical power generation and distribution system and air conditioning and pressurization system (Work Unit Code 41 of the E-3A). The ground equipment was limited to the 14 MEP-116A generators used at Tinker AFB.

The E-3A was analyzed by using the R/M attributes Mean Time Between Maintenance (MTBM), Mean Time Between Incidents (MTBI) and Maintenance Manhours per Flight Hour (MMHFH). MMHFH is commonly used by the Air Force for determining support requirements. The data used in determining the attributes come from the MDS data base in the form of two reports: The R/M Index for the E-3A and AFALD 800-4 (both are described in the Data collection section).

Comparing the specified and predicted to the assessed R/M values presented the problem of trying to determine if there was true redundancy in the system. Redundancy was an uncertainty because most aircraft have backup systems that when used dictate a mission abort for safety considerations. An example is loss of one engine inflight. The E-3A is capable of effective mission accomplishment without system degradation with only three engines operating; however, the mission would be aborted for safety. The reason is that loss of a second engine could prevent safe recovery of the aircraft. A more subtle example would be failure of the aircraft battery. Inflight the battery is used as a standby emergency power source. The actual operation of aircraft systems inflight are unaffected by the status of the battery. However, in the event of four engine flameout the battery becomes the only electrical power source available to restart the engines; therefore, mission abort. The problems of redundancy are further complicated when considering various mission profiles, peacetime vs. wartime and weather considerations. The redundancy problem led to the decision to consider logistics R numerics instead of the functional R numerics for the evaluation criteria.

The R/M data extracted from AFALD 800-4 is presented in Table 3.3.3-1. These data represent the R/M experience of an average aircraft inventory of 13.2 covering the calendar period 1 April 1978 to 30 September 1980. During this period 24575 flying hours were accumulated.

The R/M data extracted from the R/M Index is presented in Table 3.3.3-2. These data represent the R/M experience of an average aircraft inventory of 19 covering the calendar period July 1979 through June 1980. During this period 12333 flying hours were accumulated.

The R/M data extracted from the MEP-116A BLIS are presented below. These data represent the R/M experience of 14 MEP-116A generator sets covering the

TABLE 3.3.3-1: R/M DATA FROM AFALD 800-4

SYSTEM WUC	SYSTEM DESCRIPTION	MAINTENANCE EVENTS		MAINTENANCE HOURS		
		TOTAL	INHERENT	ON EQUIP	OFF EQUIP	TOTAL
11	AIRFRAME	4340	1353	11642	1901	13543
12	COCKPIT-FUSELAGE	783	303	3148	373	3521
13	LANDING GEAR	2767	1309	15733	1641	17374
14	FLT CONT SYSTEM	2510	990	9732	1599	11331
23	TURBO FAN PWR PLT	2848	1279	18619	1751	20370
24	AUX PWR PLT	835	348	3694	227	3921
41	AIR COND PRESS	2879	1175	18896	403	19299
42	ELECT PWR SUPPLY	1383	662	9531	2781	12312
44	LIGHTING	762	539	2815	234	3049
45	HYD PNEUMATIC	1007	423	5686	384	6070
46	FUEL SYSTEM	1233	631	13447	521	13968
47	OXYGEN SYSTEM	465	229	2381	112	2493
49	MISC UTILITIES	379	155	2123	119	2242
51	INSTRUMENTS	1255	758	5481	358	5839
52	AUTO PILOT	392	169	2717	103	2820
55	MALFUNCTION ANAL	83	34	514	21	535
61	HF COMM SYS	976	525	6769	536	7305
62	VHF COMM SYS	160	70	972	270	1242
63	UHF COMM SYS	1201	700	6415	566	6981
64	INTER PHONE SYS	1319	941	4817	3049	7366
65	IFF SYS	725	262	4613	1613	6226
66	EMERG COMM SYS	264	113	1374	559	1933
69	MISC COMM	613	291	2752	125	2377
71	RADIO NAVIGATION	1520	642	6164	2338	9002
72	RADAR NAVIGATION	1306	581	4835	3487	8322
81	RADAR SET	4860	1877	52625	1497	54122
82	COMPT DATA DISPLAY	4652	2584	40975	20009	60984
91	EMERG EQUIP	238	81	419	6	425
96	PERSONNEL MISC EQUIP	17	11	17	0	17
97	EXP DEV & COMP	6	0	41	0	41
TOTAL	E-3A	41778	19035	269047	47083	316130

TABLE 3.3.3-2: R/M DATA FROM R & M INDEX

SYSTEM WUC	SYSTEM DESCRIPTION	MAINTENANCE EVENTS FAILURES	MAINTENANCE EVENTS TOTAL	UNSCHEDULED MAINTENANCE MANHOURS
42ATO	INTEGRAL DRIVE GENERATOR	10	16	160
42AEO	OIL COOLER	1	1	11
42AHO	GENERATOR APU	2	8	117
42AJA	CONTROL UNIT APU GEN	4	4	36
42AJO	CONTROL APU GEN PO	4	9	50
42AJ9	NOC	1	1	10
42XXX	ELECTRICAL POWER SYSTEM	72	329	2424
24XXX	AUXILLARY POWER SYSTEM	139	372	3470
41XXX	AIR CONDITIONING & PRESS	389	1274	10308
61XXX	HF COMM SYS	230	343	3875
63XXX	UHF COMM SYS	290	505	3182
64XXX	INTER PHONE SYS	302	577	3907
65XXX	IFF SYS	100	278	1670
69XXX	MISC COMM	140	283	1461
71XXX	RADIO NAVIGATION	312	709	4727
72XXX	RADAR NAVIGATION	327	637	3984
81XXX	RADAR SET	676	1684	141296
82XXX	COMPT DATA DISPLAY	1108	2166	57488
ALL	E-3A AWACS	6542	18435	376249

calendar period January 1981 through December 1981. The AFALD 800-4 definition of a Failure Event, Other Malfunction Event and No Defect event was used.

	MAINTENANCE EVENTS	MAINTENANCE ACTIONS	MANHOURS
FAILURES	365	571	3538
OTHER MAL	34	48	194
NO DEFECT	39	65	395
TOTAL	438	684	4127

3.3.3.1 Airborne Tactical Ancillary E/M Equipment Analysis

This section presents the analyses of the achieved R/M of the ancillary E/M equipments against the specified and/or demonstrated R/M for the equipment. Achieved R/M numerics were obtained from data listed in an R&M Index (ref 37) and AFALD 800-4 (ref 52) for the airborne ancillary E/M equipment and a BLIS report for the MEP-116 generator set. The achieved R/M numerics were compared with specified R/M numerics for the equipments. The specified R/M numerics for the MEP-116 generator set were extracted from MIL-G-52884/12 (ref 53). The airborne ancillary E/M equipment allocated, predicted and demonstrated R/M numerics were extracted from Boeing R/M reports (ref 33-35) utilizing the USAF WUC manual (ref 54) to identify equipments. Table 3.3.3-3 contains a summary of the specified, allocated, predicted and demonstrated and achieved R/M numerics for both the airborne and ground ancillary E/M equipments. A description of the aircraft ancillary E/M equipment follows:

SYSTEM	COMPONENTS	WUC
AIRCRAFT POWER GENERATION	INTEGRAL DRIVE GENERATOR	42AT0
	OIL COOLER	42AE0
AIRCRAFT POWER DISTRIBUTION	ALL ELECTRICAL POWER SUPPLY SYSTEM LESS	42XXX
	INTEGRAL DRIVE GENERATOR	42AT0
	OIL COOLER	42AE0
	GENERATOR APU	42AH0
	CONTROL UNIT APU GEN	42AJA
	CONTROL APU GEN PO	42AJ0
	NOC	42AJ9
AIRCRAFT ECU	AIR CONDITIONING & PRESSURIZATION	41XXX

TABLE 3.3.3-3: ANCILLARY E/M EQUIPMENT R/M NUMERICS

ATTRIBUTE	MEP-116		AIRCRAFT POWER GENERATION (6)			AIRCRAFT POWER DISTRIBUTION (6)		
	SPECIFIED	BLIS	SPECIFIED	PREDICTED	R&M INDEX 800-4	SPECIFIED	PREDICTED	R&M INDEX 800-4
MEAN TIME BETWEEN MAINTENANCE (OPERATE HOURS) (2)								
POINT ESTIMATE	380(1)	108	472	1462	1121	146	452	247
LOWER 90% CONFIDENCE INTERVAL LIMIT		98.8			677			195
UPPER 90% CONFIDENCE INTERVAL LIMIT		118			2000			316
SINGLE-SIDED 60% CONFIDENCE LIMIT								
MEAN TIME BETWEEN MAINTENANCE (POSSESSED HOURS) (2)								
POINT ESTIMATE		336			15131			3329
LOWER 90% CONFIDENCE INTERVAL LIMIT		308			9142			2630
UPPER 90% CONFIDENCE INTERVAL LIMIT		367			26998			4272
SINGLE-SIDED 60% CONFIDENCE LIMIT								
MEAN TIME BETWEEN MAINTENANCE EVENTS (3) (OPERATE HOURS) (2)								
POINT ESTIMATE	222(4)	89.8			725			42.5
LOWER 90% CONFIDENCE INTERVAL LIMIT		82.9			484			38.6
UPPER 90% CONFIDENCE INTERVAL LIMIT		97.3			1139			47.0
SINGLE-SIDED 60% CONFIDENCE LIMIT								
MAINTENANCE MANHOURS/FLIGHT HOURS (HOURS)					0.032			0.165
MEAN DOWN TIME (HOURS)	2.0(5)	9.42						

TABLE 3.3.3-3: ANCILLARY E/M EQUIPMENT R/M NUMERICS (CONT'D)

ATTRIBUTE	AIRCRAFT ECU (6) SPECIFIED	AIRCRAFT ECU (6) PREDICTED	AIRCRAFT ECU (6) R&M INDEX	AIRCRAFT ECU (6) 800-4	AIRCRAFT PWR GEN & PWR DIST (6) SPECIFIED	AIRCRAFT PWR GEN & PWR DIST (6) PREDICTED	AIRCRAFT PWR GEN & PWR DIST (6) R&M INDEX	AIRCRAFT PWR GEN & PWR DIST (6) 800-4
MEAN TIME BETWEEN MAINTENANCE (OPERATE HOURS) (2)								
POINT ESTIMATE	116	283			111	345		
LOWER 90% CONFIDENCE INTERVAL LIMIT			31.7	20.9			58.4	24.3
UPPER 90% CONFIDENCE INTERVAL LIMIT			29.2	19.9			52.1	23.1
SINGLE-SIDED 60% CONFIDENCE LIMIT			34.5	22.0			65.7	25.6
MEAN TIME BETWEEN MAINTENANCE (POSSESSED HOURS) (2)								
POINT ESTIMATE								
LOWER 90% CONFIDENCE INTERVAL LIMIT			428	148			789	172
UPPER 90% CONFIDENCE INTERVAL LIMIT			393	141			704	163
SINGLE-SIDED 60% CONFIDENCE LIMIT			466	155			887	181
MEAN TIME BETWEEN MAINTENANCE EVENTS (3) (OPERATE HOURS) (2)								
POINT ESTIMATE								
LOWER 90% CONFIDENCE INTERVAL LIMIT			9.68	8.54			17.6	17.8
UPPER 90% CONFIDENCE INTERVAL LIMIT			9.24	8.28			16.5	16.7
SINGLE-SIDED 60% CONFIDENCE LIMIT			10.1	8.80			18.7	18.9
MAINTENANCE MANHOURS/FLIGHT HOURS (HOURS)	0.614	0.066	0.836	0.785	0.478	0.249	0.478	0.864
MEAN DOWN TIME (HOURS)								

TABLE 3.3.3-3: ANCILLARY E/M EQUIPMENT R/M NUMERICS

ATTRIBUTE	AIR VEHICLE LESS PG, PD, ECU AND EMACS (6)			
	SPECIFIED	PREDICTED	R&M INDEX	800-4
MEAN TIME BETWEEN MAINTENANCE (OPERATE HOURS) (2)				
POINT ESTIMATE	9.54	25.4		
LOWER 90% CONFIDENCE INTERVAL LIMIT			5.02	2.91
UPPER 90% CONFIDENCE INTERVAL LIMIT			4.86	2.86
SINGLE-SIDED 60% CONFIDENCE LIMIT			5.19	2.96
MEAN TIME BETWEEN MAINTENANCE (POSSESSED HOURS) (2)				
POINT ESTIMATE				
LOWER 90% CONFIDENCE INTERVAL LIMIT			67.7	20.5
UPPER 90% CONFIDENCE INTERVAL LIMIT			65.5	20.2
SINGLE-SIDED 60% CONFIDENCE LIMIT			70.0	20.9
MEAN TIME BETWEEN MAINTENANCE EVENTS (3) (OPERATE HOURS) (2)				
POINT ESTIMATE				
LOWER 90% CONFIDENCE INTERVAL LIMIT			1.33	1.26
UPPER 90% CONFIDENCE INTERVAL LIMIT			1.31	1.24
SINGLE-SIDED 60% CONFIDENCE LIMIT			1.35	1.27
MAINTENANCE MANHOURS/FLIGHT HOURS (HOURS)		11.085	12.376	4.91
MEAN DOWN TIME (HOURS)				

NOTES:

1) MINIMUM ACCEPTABLE MTBF
2) BASED ON INHERENT MAINTENANCE EVENTS FOR AFALD 800-4 AND FAILURES FOR THE R&M INDEX AND BLIS
3) BASED ON TOTAL MAINTENANCE EVENTS
4) USED DATA FROM POWER GENERATION EQUIPMENT (TABLE 3.3.2-2)
5) USED RESULTS FROM IPI REPORTS (TABLE 3.3.1-6)
6) BASED ON FLYING HOURS

SYSTEM	COMPONENTS	WUC
AIRCRAFT POWER GENERATION AND DISTRIBUTION	AUX POWER PLANT	24XXX
	ELECT POWER SUPPLY	42XXX
AIR VEHICLE	ALL EQUIPMENTS LESS AWACS	
	HF COMM SYS	61XXX
	UHF COMM SYS	63XXX
	INTER PHONE SYS	64XXX
	IFF SYS	65XXX
	MISC COMM	69XXX
	RADIO NAVIGATION	71XXX
	RADAR NAVIGATION	72XXX
	RADAR SET	81XXX
	COMPT DATA DISPLAY	82XXX
AIR VEHICLE LESS AWACS, POWER GENERATIONS, POWER DISTRIBUTION AND ECU	ALL EQUIPMENTS LESS	
	HF COMM SYS	61XXX
	UHF COMM SYS	63XXX
	INTER PHONE SYS	64XXX
	IFF SYS	65XXX
	MISC COMM	69XXX
	RADIO NAVIGATION	71XXX
	RADAR NAVIGATION	72XXX
	RADAR SET	81XXX
	COMPT DATA DISPLAY	82XXX
	AUX POWER PLANT	24XXX
	ELECT POWER SUPPLY	42XXX
	AIR CONDITIONING & PRESSURIZATION	41XXX

An adverse R/M impact was defined as an achieved R/M numeric that did not meet the allocated R/M numeric.

From one to four MEP-116As can be connected to the E-3A for maintenance. Since the number utilized varies, an estimate of operating time could not be calculated from the flying hours and ground utilization factors. An average was obtained from the following utilization data: an average of 14 units operating 5 days/week at 9 hours/day, and 2 days/week at 4.5 hours/day. These data were obtained from AWACW/MAM, Tinker AFB, OK.

The Mean Time Between Incidents (MTBI) numeric is based on the total number of maintenance events reported during a mission. The specified MTBI for the airborne equipments are:

E-3A AWACS	1.88 hours
AWACS Electronics	4.05 hours
Aircraft Power Generation (PG)	864 hours
Aircraft Power Distribution (PD)	172 hours
Aircraft ECU	24 hours

No data were obtained to calculate an achieved MTBI.

Estimates of ground operating time versus flying time for the E-3A that were obtained were:

FACTOR	SOURCE
3.0X	AWACW/MAM Tinker AFB
0.5X	AFALD 800-4

The R/M numerics given in Table 3.3.3-3 are based on flying time. The power distribution network for the E3-A is utilized for both ground and airborne operation. Based on the ground to air factors given above, the actual point estimate MTBM for the power distribution network would fall between 987 and 370 hours, and the point estimate MTBME would fall between 171 and 64 hours.

The airborne ECU equipment is normally not used during maintenance on the ground. A trailer mounted air filter, type GSU-266/E is used on the flightline to filter conditioned air required by E3-A airplane mission avionic equipment during operation and maintenance. The predicted MTBF is 11,402 hours, the specified is 4,000 hours. A trailer mounted cooling cart provides a means of removing heat loads from the AWACS aircraft liquid cooling system during periods of extended ground operation of the aircraft Surveillance Radar Functional Group. The specified MTBF is "Not-Less-Than-500-Hours" and a MTBI of "Not-Less-Than-250-Hours." The predicted MTBF is 514 hours. The specified MTTR is 2.5 hours and the specified maintenance manhours per operating hour is "Not-Greater-Than- 0.10." No achieved R/M numerics were obtained for these equipments.

3.3.3.2 Airborne Tactical Ancillary E/M Equipment Results

The following list of equipment-attributes satisfied the definition of an adverse impact:

EQUIPMENT	ATTRIBUTE
AIRCRAFT POWER GENERATION (PG)	MTBME
AIRCRAFT POWER DISTRIBUTION (PD)	MTBME
AIRCRAFT ECU (ECU)	MTBM MTBME MMHFH
AIRCRAFT POWER GENERATION AND DISTRIBUTION	MTBM MTBME MMHFH
AIR VEHICLE LESS PG, PD, ECU AND AWACS ELECTRONICS	MMHFH
MEP-116A	MTBM MTBME MDT

As can be seen all of the airborne equipment failed to meet the MTBME standard, regardless of the data source. The aircraft ECU, and the aircraft total Power Generation and Power Distribution system and Air Vehicle failed to meet the MTBM and MMHFH standards. The MEP-116A failed to meet the MTBM, MTBME and MDT standards. Even given the ground-to-air factors of 3.0 or 0.5, the Power Distribution System still does not meet the MTBME standard.

3.3.3.3 Airborne Tactical C^{3}I System Analysis

This section presents the analyses of the achieved R/M of ancillary E/M equipments as a percentage of the system R/M. The achieved Mean Time Between Maintenance (MTBM), Mean Time Between Maintenance Events (MTBME) and Mean Man hours per Flight Hour (MMHFH) for the system, AWACS electronics and ancillary E/M equipments were summarized from data obtained from BLIS, AFALD 800-4 and R&M Index reports, and the percent system contribution of the ancillary E/M equipments was calculated. The percentage was then compared with the percentage anticipated by the specified and/or predicted values (where available). An adverse impact was defined as a higher achieved percentage than the specified value.

The specified (allocated) MTBF, and MMHFH are based on the airborne configuration. No specified ground (allocated) ground configuration R/M numerics were given; however, R/M numerics are a function of the environmental stresses applied to the equipments. A recent RADC study, Revision Of Environmental Factors For MIL-HDBK-217, (ref 55) showed that the Ground, Mobile (GM) environment and the Airborne, Inhabited, Transport (AIT) environment are comparable; the GM environment had a Environmental Severity Ratio (ESR) of 11.5 and the AIT had an ESR of 10.2. The GM environment was ranked 8th least severe and the AIT 7th least severe out of all the MIL-HDBK-217 environmental categories; therefore, the specified (allocated) R numeric for the system ground configuration was assumed to be the same as what was specified (allocated) for the airborne configuration. The E-3A AWACS system specified and achieved MTBF numeric were revised to include four MEP-116A generator sets using the equation:

$$\frac{1}{\text{MTBF(SYSTEM, REVISED)}} = \frac{1}{\text{MTBF(POWER DISTRIBUTON)}} + \frac{1}{\text{MTBF(AWACS)}}$$

$$\frac{1}{\text{MTBF(AIR FORCE)}} + \frac{2}{\text{MTBF(MEP-116A)}}$$

No specified MMHFH numerics were given for the MEP-116A. Table 3.3.3-4 contains the specified and achieved R/M numerics. The achieved R/M numerics for the airborne equipment are based on the R&M Index Report. The achieved R/M numerics for the MEP-116A are based on the BLIS. The Logistics Configuration Reliability Block Diagram and Math Model is shown in Figure 3.3.3-1 for the airborne equipment arrangement and in Figure 3.3.3-2 for the ground equipment arrangement.

The MTBM and MTBME calculations for the system ground configurations are based on an estimate of 19656 system operating hours, which in turn is based on an average of 2 MEP-116As needed to perform maintenance on the E-3A AWACS system, and the MEP-116A operating time estimate provided by AWACW/MAM, Tinker AFB, OK.

TABLE 3.3.3-4: E-3A AWACS R/M NUMERICS

EQUIPMENT	ATTRIBUTE	AIRBORNE SPECIFIED	AIRBORNE PREDICTED	R&M INDEX (4)	GROUND SPECIFIED	GROUND PREDICTED	R&M INDEX (5)	R&M INDEX (6)
SYSTEM	MTBM (OPERATE HOURS)							
	POINT ESTIMATE	2.98	6.79	1.89	3.08(3)		3.00	4.89
	LOWER 90% CONFIDENCE INTERVAL LIMIT			1.85			2.94	4.79
	UPPER 90% CONFIDENCE INTERVAL LIMIT			1,92			3.07	4.99
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE			25.4			25.4	25.4
	LOWER 90% CONFIDENCE INTERVAL LIMIT			24.9			24.9	24.9
	UPPER 90% CONFIDENCE INTERVAL LIMIT			26.0			26.0	26.0
	MTBME (OPERATE HOURS)							
	POINT ESTIMATE			0.67			1.07	1.74
	LOWER 90% CONFIDENCE INTERVAL LIMIT			0.66			1.05	1.71
	UPPER 90% CONFIDENCE INTERVAL LIMIT			0.68			1.08	1.76
	MAINTENANCE MANHOURS/FLIGHT HOUR	28.007	14.720	30.508				
	MAINTENANCE MANHOURS/OPERATE HOUR						19.142	11.762
AWACS ELECTRONICS	MTBM (OPERATE HOURS)							
	POINT ESTIMATE	4.81	9.86	3.54	4.81	9.86	5.64	9.18
	LOWER 90% CONFIDENCE INTERVAL LIMIT			3.44			5.48	8.93
	UPPER 90% CONFIDENCE INTERVAL LIMIT			3.64			5.80	9.44
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE			47.8			47.8	47.8
	LOWER 90% CONFIDENCE INTERVAL LIMIT			46.4			46.4	46.4
	UPPER 90% CONFIDENCE INTERVAL LIMIT			49.1			49.1	49.1
	MTBME (OPERATE HOURS)							
	POINT ESTIMATE			1.72	4.05		2.74	4.45
	LOWER 90% CONFIDENCE INTERVAL LIMIT			1.68			2.68	4.37
	UPPER 90% CONFIDENCE INTERVAL LIMIT			1.75			2.79	4.54
	MAINTENANCE MANHOURS/FLIGHT HOUR	6.967	3.321	17.27	6.967	3.321		
	MAINTENANCE MANHOURS/OPERATE HOUR						11.273	6.927

TABLE 3.3.3-4: E-3A AWACS R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	AIRBORNE SPECIFIED	AIRBORNE PREDICTED	AIRBORNE R&M INDEX (4)	GROUND SPECIFIED	GROUND PREDICTED	GROUND R&M INDEX (5)	GROUND R&M INDEX (6)
AIRCRAFT(AC)	MTBM (OPERATE HOURS)							
POWER	POINT ESTIMATE	472	1462	1121				
GENERATION	LOWER 90% CONFIDENCE INTERVAL LIMIT			677				
	UPPER 90% CONFIDENCE INTERVAL LIMIT			2000				
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE			15131				
	LOWER 90% CONFIDENCE INTERVAL LIMIT			9142				
	UPPER 90% CONFIDENCE INTERVAL LIMIT			26998				
	MTBME (OPERATE HOURS)							
	POINT ESTIMATE			725				
	LOWER 90% CONFIDENCE INTERVAL LIMIT			484				
	UPPER 90% CONFIDENCE INTERVAL LIMIT			1139				
	MMHFH			0.032				
	MMHOH							
AIRCRAFT	MTBM (OPERATE HOURS)							
POWER	POINT ESTIMATE	146	452	247	146	452	393	640
DISTRIBUTION	LOWER 90% CONFIDENCE INTERVAL LIMIT			195			310	505
	UPPER 90% CONFIDENCE INTERVAL LIMIT			316			504	821
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE			3329			3329	3329
	LOWER 90% CONFIDENCE INTERVAL LIMIT			2630			2630	2630
	UPPER 90% CONFIDENCE INTERVAL LIMIT			4272			4272	4272
	MTBME (OPERATE HOURS)							
	POINT ESTIMATE			42.5		172	67.8	110
	LOWER 90% CONFIDENCE INTERVAL LIMIT			38.6			61.5	100
	UPPER 90% CONFIDENCE INTERVAL LIMIT			47.0			74.9	122
	MMHFH			0.165				
	MMHOH						0.104	0.064

TABLE 3.3.3-4: E-3A AWACS R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	AIRBORNE SPECIFIED	AIRBORNE PREDICTED	AIRBORNE R&M INDEX (4)	GROUND SPECIFIED	GROUND PREDICTED	GROUND R&M INDEX (5)	GROUND R&M INDEX (6)
AIRCRAFT POWER GENERATION AND DISTRIBUTION	MTBM (OPERATE HOURS)							
	POINT ESTIMATE	111	345	58.4				
	LOWER 90% CONFIDENCE INTERVAL LIMIT			52.1				
	UPPER 90% CONFIDENCE INTERVAL LIMIT			65.7				
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE			789				
	LOWER 90% CONFIDENCE INTERVAL LIMIT			704				
	UPPER 90% CONFIDENCE INTERVAL LIMIT			887				
	MTBME (OPERATE HOURS)							
	POINT ESTIMATE			17.6				
	LOWER 90% CONFIDENCE INTERVAL LIMIT			16.5				
	UPPER 90% CONFIDENCE INTERVAL LIMIT			18.7				
	MMHFH	0.478	0.249	0.478				
	MD							
AIRCRAFT ECU	MTBM (OPERATE HOURS)							
	POINT ESTIMATE	116	283	31.7				
	LOWER 90% CONFIDENCE INTERVAL LIMIT			29.2				
	UPPER 90% CONFIDENCE INTERVAL LIMIT			34.5				
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE			428				
	LOWER 90% CONFIDENCE INTERVAL LIMIT			393				
	UPPER 90% CONFIDENCE INTERVAL LIMIT			461				
	MTBME (OPERATE HOURS)							
	POINT ESTIMATE			9.68				
	LOWER 90% CONFIDENCE INTERVAL LIMIT			9.24				
	UPPER 90% CONFIDENCE INTERVAL LIMIT			10.10				
	MMHFH	0.614	0.066	0.836				
	MMHOH							

TABLE 3.3.3-4: E-3A AWACS R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	AIRBORNE SPECIFIED	AIRBORNE PREDICTED	AIRBORNE R&M INDEX (4)	GROUND SPECIFIED	GROUND PREDICTED	GROUND R&M INDEX (5)	R&M INDEX (6)
AIRFRAME	MTBM (OPERATE HOURS)							
	POINT ESTIMATE	9.54	25.4	5.02	9.54	25.4	8.00	13.0
	LOWER 90% CONFIDENCE INTERVAL LIMIT			4.86			7.74	12.59
	UPPER 90% CONFIDENCE INTERVAL LIMIT			5.19			8.27	13.46
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE			67.7			67.7	67.7
	LOWER 90% CONFIDENCE INTERVAL LIMIT			65.5			65.5	65.5
	UPPER 90% CONFIDENCE INTERVAL LIMIT			70.0			79.0	70.0
	MTBME (OPERATE HOURS)							
	POINT ESTIMATE			1.33		172	2.12	3.45
	LOWER 90% CONFIDENCE INTERVAL LIMIT			1.31			2.08	3.39
	UPPER 90% CONFIDENCE INTERVAL LIMIT			1.35			2.16	3.51
	MMHFH		11.085	12.210		11.085		
	MMHOH						7.765	4.771
MEP-116A	MTBM (OPERATE HOURS)							
	POINT ESTIMATE				190		53.8	
	LOWER 90% CONFIDENCE INTERVAL LIMIT						49.4	
	UPPER 90% CONFIDENCE INTERVAL LIMIT						58.8	
	MTBM (POSSESSED HOURS)							
	POINT ESTIMATE						168	
	LOWER 90% CONFIDENCE INTERVAL LIMIT						154	
	UPPER 90% CONFIDENCE INTERVAL LIMIT						184	
	MTBME (OPERATE HOURS)							
	POINT ESTIMATE					111(2,3)	44.9	
	LOWER 90% CONFIDENCE INTERVAL LIMIT						41.5	
	UPPER 90% CONFIDENCE INTERVAL LIMIT						48.6	
	MMHFH							
	MDHOH						0.210	
	MD				2.0(1)			

TABLE 3.3.3-4: E-3A AWACS R/M NUMERICS (CONT'D)

EQUIPMENT	ATTRIBUTE	AIRBORNE			GROUND			
		SPECIFIED	PREDICTED	R&M INDEX (4)	SPECIFIED	PREDICTED	R&M INDEX (5)	R&M INDEX (6)

NOTES:

1) USED DATA FROM POWER GENERATION EQUIPMENT (TABLE 3.3.2-2)
2) USED RESULTS FROM IPT REPORTS (TABLE 3.3.1-6)
3) ASSUMED AN AVERAGE OF TWO MEP-116As ARE USED
4) BASED ON FLYING HOURS
5) BASED ON GROUND HOURS
6) BASED ON GROUND AND FLYING HOURS

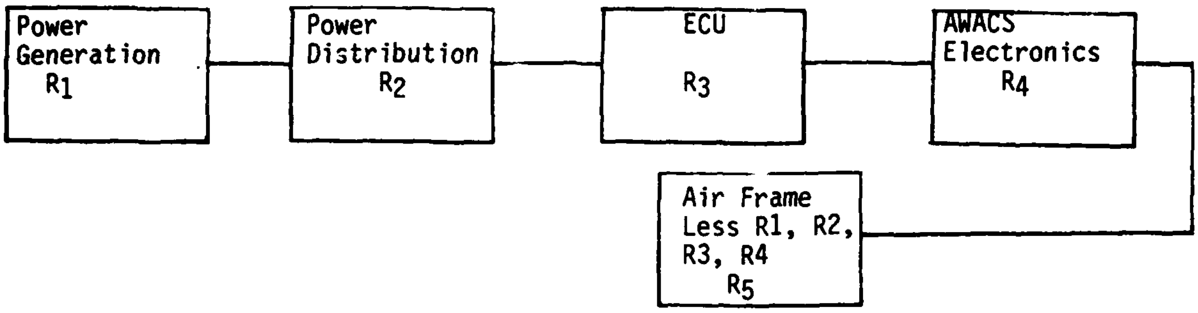


FIGURE 3.3.3-1: E-3A AWACS LOGISTICS CONFIGURATION
AIRBORNE RELIABILITY BLOCK DIAGRAM

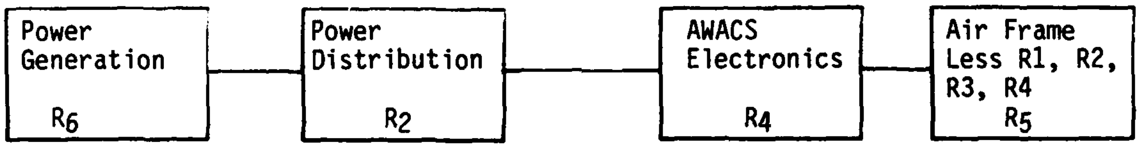


FIGURE 3.3.3-2: E-3A AWACS LOGISTICS CONFIGURATION
GROUND RELIABILITY BLOCK DIAGRAM

3.3.3.4 E-3A AWACS Results

The percent specified (allocated or predicted) and achieved MTBM, MTBME, and MMHFH contribution of the power generation, power distribution, ECU, airframe and AWACS electronics to the E-3A AWACS system are given below for the airborne configuration.

AIRBORNE SYSTEM CONFIGURATION

EQUIPMENT	PERCENT CONTRIBUTION MTBM		MTBME		MMHFH	
	SPECIFIED	ACHIEVED	SPECIFIED	ACHIEVED	PREDICTED	ACHIEVED
AWACS ELECTRONICS	63.0	53.4	--	40.3	22.6	56.1
PWR GEN	0.6	0.2	--	0.1	--	--
PWR DIST	2.0	0.8	--	1.6	--	--
PWR GEN & PWR DIST	2.7	3.2	--	--	1.7	1.6
ECU	2.6	6.0	--	7.0	0.4	2.7
AIRFRAME	31.7	37.6	--	51.0	75.3	36.6

It was not feasible to construct a table similar to the one above for the ground configuration because it could not be determined in which environment the failures occurred. The ground configuration data do show that the MEP-116A MTBM is 6X better than the AWACS electronics MTBM, the MEP-116A MTBME is 10X better than the AWACS electronics MTBME, and the MEP-116A MMHOH is 33X better than the AWACS electronics MMHOH. The data also show that the Aircraft Power Distribution (PD) system MTBM is 70X better than the AWACS electronics MTBM, the Aircraft PD system MTBME is 25X better than the AWACS electronics MTBME, and the Aircraft PD system MMHOH is 108X better than the AWACS electronics MMHOH.

4.0 INVESTIGATION OF R/M ASSESSMENT TECHNIQUES

4.1 Equipment Reliability Specification and Demonstration

It is generally recognized that the reliability requirement and the test to demonstrate that the requirement has been satisfied must be rigorously specified. The characteristics which must be specified to use the MIL-STD-781 test plans are:

- o the acceptable reliability value, θ_0
- o The unacceptable reliability value (previously called minimum acceptable reliability) θ_1
- o producer's risk
- o consumer's risk
- o the failure probability distribution
- o the test plan

The reliability requirements for the engine generators, motor generators, and the environmental control units used with the 407L system were reviewed to assess their completeness in terms of these criteria. The reliability requirements are shown in summary form in Table 4.1-1 for engine generators, Table 4.1-2 for motor generators, and Table 4.1-3 for air conditioners.

It is obvious from these tables that none of the specifications contain adequately stated reliability specification or demonstration requirements. The situation is compounded by the fact that in many instances the requirements are not correctly stated or will lead to conclusions having questionable statistical validity.

In all cases the exponential distribution has been assumed. While such an assumption is attractive owing to the tractability of the related mathematics and the availability of MIL-STD-781 test plans, it does not excuse the use of what may be an erroneous and costly assumption. No evidence was found during this study to either confirm or refute the validity of the assumption. None the less, the fact that the major failure mechanisms of engine generators and air conditioners are time dependent is sufficient to view the exponential assumption with suspicion.

TABLE 4.1-1: ENGINE GENERATOR RELIABILITY REQUIREMENTS

	G.T.E.D. GENERATOR 60KW, 400HZ EMU-30/U AND MEP404A	DED GENERATOR 400HZ EMU-21/U (30KW) AND EMU-22/U (60KW)
SPECIFICATION	MIL-G-83380	MIL-G-38441C
ACCEPTABLE RELIABILITY	NOT GIVEN	NOT GIVEN
UNACCEPTABLE RELIABILITY	SPECIFIED MTBF NOT LESS THAN 500 HOURS	MIMIMUM OPERATING LIFE OF 1000 HOURS BETWEEN MINOR OVERHAULS
CONSUMER"S RISK	20%	10%
PRODUCERS RISK	20%	--
FAILURE DISTRIBUTION	NOT DIRECTLY STATED. ASSUMED, BY REFERENCE TO MI1-STD-781, TO BE EXPONENTIAL	EXPONENTIAL ASSUMED
TEST PLAN	DATA GENERATED DURING ENDURANCE TEST EVALUATED BY TEST PLAN IV, MIL-STD-781 MODIFIED BY 1,500 HOUR TERMINATION OF THE TEST PLAN	ACCEPT ON ZERO FAILURES DURING PRE-PRODUCTION TESTING, OTHERWISE ACCEPT WHERE $t > \frac{X^2(2r + 2), 0.1 (MTBF)}{2}$ WITH t NOT TO EXCEED 1500 HOURS

TABLE 4.1-2: MOTOR GENERATOR RELIABILITY REQUIREMENTS

	MOTOR GENERATOR, 400HZ PRECISE OUTPUT MIL-M-48030	
	MD-2 (10KW)	MD-4 (50KW)
SPECIFICATION	MIL-M-48180	MIL-M-4820E
ACCEPTABLE RELIABILITY	4000 HOURS	SAME
UNACCEPTABLE RELIABILITY	1000 HOURS	SAME
CONSUMER'S RISK	---	---
PRODUCER'S RISK	---	---
FAILURE DISTRIBUTION	NOT DIRECTLY STATED. ASSUMED, BY REFERENCE TO MIL-STD-781, TO BE EXPONENTIAL	SAME
TEST PLAN	FOUR UNITS OPERATED FOR 625 HOURS EACH FOR TOTAL TEST TIME OF 2500 HOURS ACCEPT ON ONE FAILURE. REJECT ON TWO FAILURES.	SAME

TABLE 4.1-3: AIR CONDITIONER RELIABILITY REQUIREMENTS

	COMPACT LIGHTWEIGHT AIR CONDITIONERS, MIL-A-38339D 18,000 BTU/HOUR A/E32C-17, 208V, 60/50 HZ, 3 PHASE, MIL-A-38269 A/E32C-18, 208V, 400 HZ, 3 PHASE, MIL-A-38340 36,000 BTU/HOUR A/E32-24, 208V, 60/50HZ, 3 PHASE, MIL-A-38345 A/E32-25, 208V, 400HZ, 3 PHASE, MIL-A-38346 54,000 BTU/HOUR A/E32C-26, 208V, 60/50HZ, 3 PHASE, MIL-A-38347 A/E32C-27, 208V, 400HZ, 3 PHASE, MIL-A-38348
ACCEPTABLE RELIABLITY	--
UNACCEPTABLE RELIABILITY	434 HOURS MINIMUM
CONSUMER'S RISK	10%
PRODUCER'S RISK	--
FAILURE DISTRIBUTION	EXPONENTIAL ASSUMED
TEST PLAN	ACCEPT GIVEN ZERO FAILURES OCCUR DURING PREPRODUCTION TESTING.

The sequential test plans of MIL-STD-781, under the exponential assumption are most attractive since with various trade offs of discrimination ratio and risks, total test time can be held to a minimum. Further where the true θ closely approaches either the upper test limit, θ_0, or the lower test limit θ_1, a very early accept or reject decision can be made.

A literature search for test plans applicable to the Weibull distribution and analogous to those of MIL-STD-781 revealed that little work has been done in this area. One deterrent lies in the fact that while the exponential total test time and accept/reject criteria are linearly related to the lower test level θ_1, such is not the case for the general Weibull where the relationship is the b th root of the sum of the b th power of the times-to-failure (TTF) for a Weibull slope of b

$$\left(\left[\sum_{i=1}^{r} [TTF]_i^b\right]^{1/b} \right).$$

In spite of this difficulty, in the course of this study a Weibull sequential test plan similar to those of MIL-STD-781C was developed and is presented in Figure 4.1-1. This development is based on the following inequalities for the accept/reject criteria for the Weibull distribution of failures resulting from sequential (variables) testing (ref 56):

Accept Ho if

$$\sum_{i=1}^{r} x_i^b > \frac{\theta_o^b}{d^b-1}\left[b \cdot r \cdot \ln(d) + \ln\left(\frac{1-\beta}{\alpha}\right)\right] \tag{1}$$

Reject Ho (Accept Hi) if

$$\sum_{i=1}^{r} x_i^b < \frac{\theta_o^b}{d^b-1}\left[b \cdot r \cdot \ln(d) + \ln\left(\frac{\beta}{1-\alpha}\right)\right] \tag{2}$$

where H_0 is the null hypothesis that the true θ is θ_0

H_1 is the alternative that the true θ is θ_1

θ_0 is the upper test limit (acceptable) Weibull characteristic life
θ_1 is the lower test limit (unacceptable) Weibull characteristic life
d is the discrimination ratio (θ_0/θ_1)
b is the Weibull shape parameter
α is the risk of incorrect rejection
β is the risk of incorrect acceptance
r is the number of failures observed
x_i is the survival time of the ith item tested
ln denotes natural logorithm.

There are three decisions to be made as follows:

D_1-accept H_0
D_2-Reject H_0
D_3-continue test when neither D_1 or D_2 can be made.

Where the decision is to continue testing, the minimum additional test time required to accept, given no failure occurs, may be computed by solving the following equality:

$$t_{D3} = \left[\frac{(d \cdot \theta_1)^b}{d^b - 1} \left[b \cdot r \cdot \ln(d) + \ln\left(\frac{1-\beta}{\alpha}\right)\right] - \sum_{i=1}^{r} x_i^b\right]^{1/b} \tag{3}$$

The accept/reject boundaries for the test plan shown in Figure 4.1-1 were obtained by evaluating the following identities which are based on the previously stated accept/reject inequalities (1) and (2).

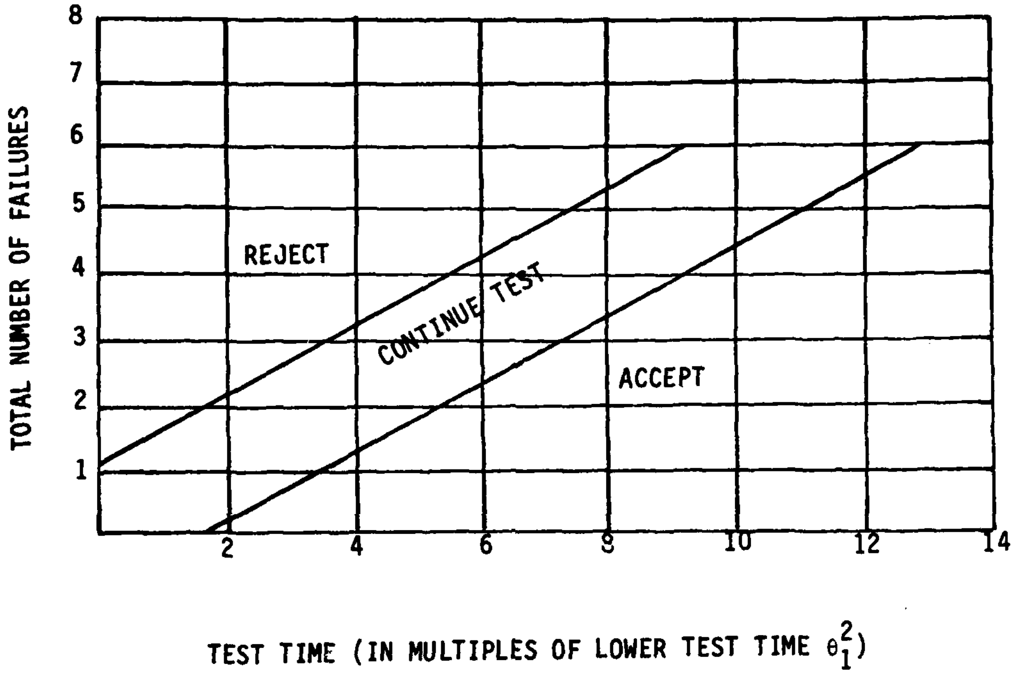
Accept

$$k_a = \frac{d^b}{d^b - 1} \left[b \cdot r \cdot \ln(d) + \ln\left(\frac{1-\beta}{\alpha}\right)\right] \tag{4}$$

Reject

$$k_r = \frac{d^b}{d^b - 1} \left[b \cdot r \cdot \ln(d) + \ln\left(\frac{\beta}{1-\alpha}\right)\right] \tag{5}$$

Weibull Distribution b = 2
Decision Risks (Nominal) 20 percent
Discrimination Ratio 2.0 : 1



NUMBER OF FAILURES	REJECT (EQUAL OR LESS)	ACCEPT (EQUAL OR MORE)
0	N/A	1.85
1	N/A	3.69
2	1.85	5.54
3	3.69	7.39
4	5.52	9.24
5	7.39	11.09
6	9.24	12.96

FIGURE 4.1-1: TEST PLAN Z

where

k = multiples of lower test time θ_1^b

$d = 2.0:1$

$b = 2$

$\beta = .20$

$\alpha = .20$

It should be noted that equalities 4 and 5 may be used to establish the accept/reject boundries for other values of d, b, β, and α. An understanding of equations 1, 2, 3 and Figure 4.1-1 can be best conveyed by a series of five examples.

EXAMPLE 1

It is required that a mechanical equipment shall have a lower test level θ_1 of 135 hours and an upper test level θ_0 of 270 hours, i.e., a discrimination ratio (d) of 2.0:1. A sequential test with β and α risks of 0.20 shall be used to demonstrate achievement of the requirement. A Weibull distribution of failure is assumed; however, the slope, b, is unknown.

Three equipments when tested to failure, result in life times of 140 hours, 230 hours, and 350 hours. These data when plotted on Weibull probability paper with the plotting positions adjusted for median rank (ref 56) indicates a Weibull slope, b, of approximately 2 as shown by Figure 4.1-2.

Neither a D_1(accept) nor D_2(reject) decision is reached based on the first 2 life times and testing is continued. The third attempt at a D_1 decision is as follows:

$$(140)^2 + (230)^2 + (350)^2 > \frac{(270)^2}{2^2-1}\left((2)\ (3)\ (\ln 2) + \ln\left(\frac{1-.20}{.20}\right)\right)$$

$$195000 > 134719.2$$

With the inequality satisfied it has been demonstrated that the true θ is more likely 270 than 135. As with all sequential tests no measure of the true θ has been made. The total test time was 720 hours.

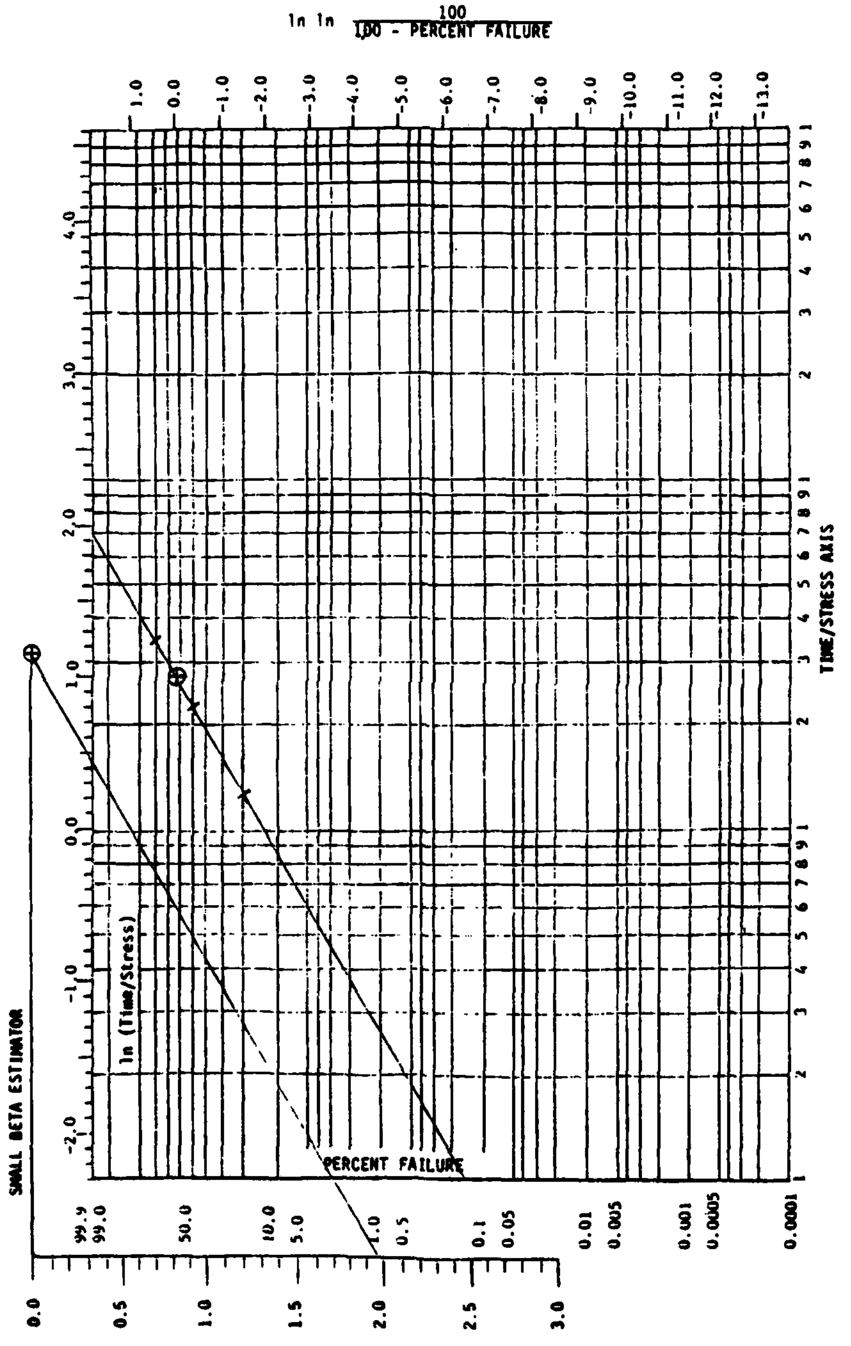


FIGURE 4.1-2: EXAMPLE 1 TIME TO FAILURE WEIBULL PLOT

Example 2

The same equipment as in Example 1 with identical requirements except that the Weibull slope is known to be 2 and is so specified. Thus Test Plan Z, Figure 4.1-1 is specified.

The first equipment tested again fails at 140 hours or 1.08 multiples of θ_1^2, i.e., $(140)^2/(135)^2$, (see Figure 4.1-3) resulting in a D_3 decision. Using equation 3 it is found that an accept decision can be made if the second equipment survives at least 219 hours.

$$t_{D3} = \left[\frac{4(135)^2}{3} \left[(2)\ (1)\ (.693) + 1.386\right] - (140)^2 \right]^{1/2} = 218.5 \text{ Hours}$$

This is equivalent to $2.62\theta_1^2$.

The second equipment survives for the required 218.5 hours resulting in an D_1 decision. It has been shown again that the true θ is more likely 270 hours than 135 hours. The total minimum test time was 358.5 hours.

Example 3

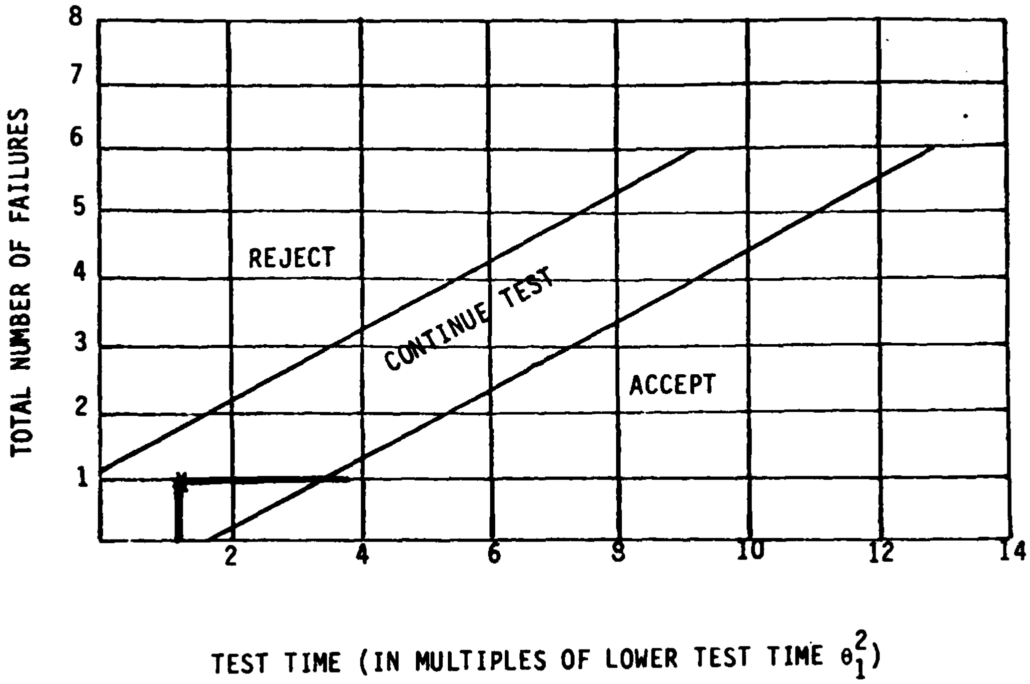
The equipment and the requirements are the same as in Example 1 except that it is erroneously assumed that the failure distribution is exponential and Test Plan IVC of MIL-STD-781C is specified.

The failure times 140, 230, and 350 are shown graphically in Figure 4.1-4. The decision after 3 failures and 720 hours of test time is to continue testing.

These three examples show the advantage in terms of test time of the specification of a valid test plan. The value in terms of cost is quite clear where in example 2 an accept decision is reached in 358.5 hours as compared to the continue test decision after 720 hours of testing which was reached by erroneously using test plan IVC (example 3).

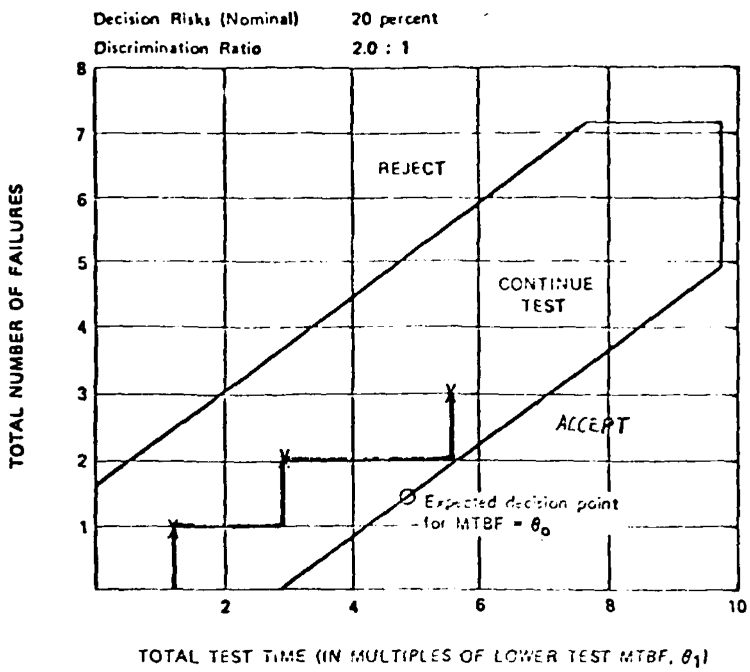
It has been earlier stated that sequential testing will also provide early rejection where θ approaches the value of θ_1. The following two examples using

Weibull Distribution	b = 2
Decision Risks (Nominal)	20 percent
Discrimination Ratio	2.0 : 1



NUMBER OF FAILURES	REJECT (EQUAL OR LESS)	ACCEPT (EQUAL OR MORE)
0	N/A	1.85
1	N/A	3.69
2	1.85	5.54
3	3.69	7.39
4	5.52	9.24
5	7.39	11.09
6	9.24	12.96

FIGURE 4.1-3: TEST PLAN Z, EXAMPLE 2



Number of Failures	Total Test Time* Reject (Equal or less)	Total Test Time* Accept (Equal or more)
0	N/A	2.80
1	N/A	4.18
2	.70	5.58
3	2.08	6.96
4	3.46	8.34
5	4.86	9.74
6	6.24	9.74
7	7.62	9.74
8	9.74	N/A

* Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.2.4 for minimum test time per equipment.

FIGURE C-4. Accept-reject criteria for Test Plan IVC.

FIGURE 4.1-4: TEST PLAN IVC, EXAMPLE 3

test plan Z and IVC illustrate the consequences of using the valid test plan under this condition.

Example 4

The requirements of example 1 apply, the Weibull slope, b, is known to be 2, and test plan Z is specified. The times to failure are 70, 115, and 170 hours. When plotted, Figure 4.1-5, a reject decision is reached in 0.99 multiples of θ_1^2 or 185 hours of testing.

Example 5

The equipment and requirements are the same as in example 4 except that it is erroneously assumed that the failure distribution is exponential and test plan IVC of MIL-STD-781C is specified.

The failure times 70, 115, and 170 are shown graphically in Figure 4.1-6. The decision after 3 failures and 355 hours of testing is to continue testing.

4.2 System Reliability Specification, Prediction and Demonstration

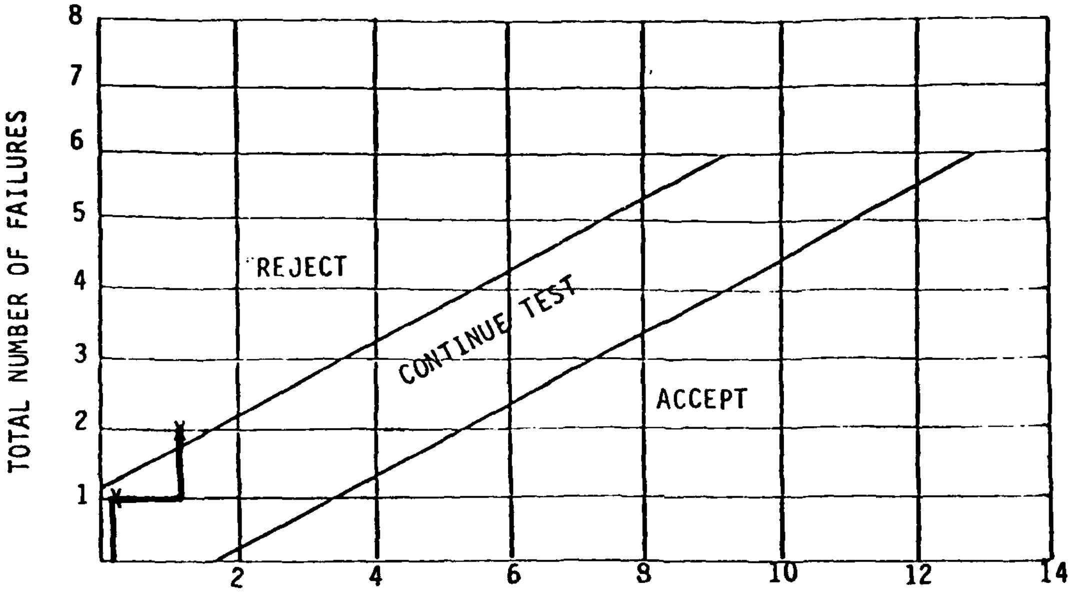
The reliability requirements of the AN/TSC-60(V), AN/TSQ-XX and E-3A AWACS systems were reviewed to determine the level to which reliability is predicted. The review of these requirements is presented in the following paragraphs along with a description of a preferred prediction methodology.

The AN/TSC-60(V) system level predictions and reliability math models did not include the power generation, power conversion or ECU equipments. The power distribution network was included but it was not broken out so that its impact on system reliability was not readily discernible. The AN/TSQ-XX systems level predictions and reliability math models included the power, ECU and power distribution equipment; however, the predictions did not treat both power generation and power conversion equipments. The E-3A AWACS system level prediction and reliability math model included the airborne ancillary equipments. Reliability predictions were given for the ground ancillary E/M equipments, but no system level reliability math model was found that included

Weibull Distribution b = 2

Decision Risks (Nominal) 20 percent

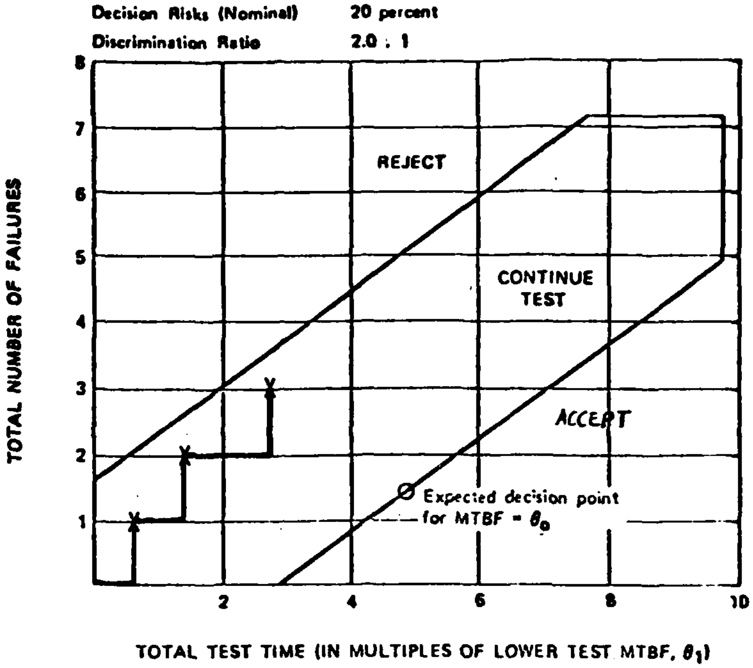
Discrimination Ratio 2.0 : 1



TEST TIME (IN MULTIPLES OF LOWER TEST TIME θ_1^2)

NUMBER OF FAILURES	REJECT (EQUAL OR LESS)	ACCEPT (EQUAL OR MORE)
0	N/A	1.85
1	N/A	3.69
2	1.85	5.54
3	3.69	7.39
4	5.52	9.24
5	7.39	11.09
6	9.24	12.96

FIGURE 4.1-5: TEST PLAN Z, EXAMPLE 4



Total Test Time*

Number of Failures	Reject (Equal or less)	Accept (Equal or more)
0	N/A	2.80
1	N/A	4.18
2	.70	5.58
3	2.08	6.98
4	3.46	8.34
5	4.86	9.74
6	6.24	9.74
7	7.62	9.74
8	9.74	N/A

* Total test time is total unit hours of equipment on time and is expressed in multiples of the lower test MTBF. Refer to 4.5.2.4 for minimum test time per equipment.

Accept-reject criteria for Test Plan IVC.

FIGURE 4.1-6: TEST PLAN IVC, EXAMPLE 5

these equipments. Since estimates of from 33% to 75% of the operating time of the AWACS is spent using the ground ancillary E/M equipments, a model should have been specified that includes these equipments.

The reliability predictions for the ancillary E/M equipments used with both the E3-A AWACS and AN/TSQ-XX equipments were given as averages based on historical data from similar equipments. This method of prediction is an accepted method that has been used in industry for both electronic and nonelectronic equipments. The AN/TSQ-XX power distribution networks reliability predictions were based on the detailed stress analysis method on RADC Reliability Notebook, Volume II.

The system level reliability predictions should include consideration of the power and ECU equipments. The contractor should be required to make two predictions whenever Government Furnished Equipment (GFE) is provided, one for Contractor Furnished Equipment (CFE) and one for both CFE and GFE. Furthermore this requirement should be imposed on every possible system configuration; for example, airborne and ground for the AWACS, and using engine generators and motor generators for the AN/TSQ-XX and AN/TSC-60(V) systems.

The reliability requirements of the AN/TSC-60(V), AN/TSQ-XX and E-3A AWACS systems were reviewed to determine the level to which reliability is demonstrated. The review of these requirements is presented in the following paragraphs along with a description of a preferred demonstration methodology.

The AN/TSC-60(V) reliability demonstration did not include the power and ECU equipments associated with the system. The AN/TSQ-XX reliability demonstration test plan included provisions for power conversion using motor generators, and air conditioning using the Air Conditioning Modules (ACM). The demonstration test was conducted using factory supplied air conditioning because the GFE air conditioners were not available. The E-3A AWACS reliability demonstration included the air vehicle, but did not include the GFE AGE.

The power and ECU equipment for the AN/TSC-60(V) and AN/TSQ-XX systems were provided to the contractor as GFE. The contractor can not be held contractually responsible for the reliability of these equipments; therefore, they can not be included in the reliability test accept-reject decision. They should, however, be a part of the demonstration test so that interface, sneak circuit, power surge, ECU thermal response, etc. problems are identified prior to deployment. Failures of these equipments would be classified as non-relevant for accept-reject purposes, but could be summed with the relevant failures to ascertain whether the system met the minimum acceptable reliability requirement.

The ground power and ECU equipments for a system such as the E-3A AWACS whether they are CFE or GFE are difficult to include in a system level MIL-STD-781 demonstration test when the airborne power and ECU equipments are also CFE or GFE. Two demonstration tests would be necessary because one can not call out a MIL-STD-781 sequential test plan for a system and then test equipments separately. An example will serve to illustrate this. Given that the specified system reliability is 272 hours, and this is allocated to the equipments as follows: ECU - 700 hours, power generation - 800 hours and electronics - 1000 hours. If the system is tested to MIL-STD-781C Test Plan IV C and if each equipment fails once at any time prior to 272 hours into the test, the system would fail the test (3 failures). However, if each equipment were tested separately and each failed once during the test and prior to 272 hours, all three equipments would pass the test. Therefore the accept-reject criteria are different and the results obtained if one tested each equipment separately may be erroneous.

Since it is probably not feasible due to cost and time constraints to conduct two reliability demonstration tests, whenever GFE are provided as part of an electronics systems, the Contracting Officer should allocate the system reliability requirement to the electronics and GFE. The resultant allocated electronics reliability numeric should be called out as the specified reliability numeric for the electronics. The Contracting Officer should then provide the GFE that have demonstrated the allocated reliability numeric. The Government should specify that the GFE be utilized in the reliability demonstration test so that there is a greater probability that problem areas are found prior to deployment.

4.3 Maintainability Specification, Prediction and Demonstration

The maintainability requirements of several power and ECU equipments were reviewed to determine the level to which maintainability is specified, predicted and demonstrated. Table 4.1-4 contains excerpted paragraphs which detail the maintainability requirements called out in the specifications. As can be seen these requirements vary from none specified to the detailed requirement called out in MIL-A-52767B.

Of the ancillary E/M equipments used with the AN/TSC-60, AN/TSQ and AWACS systems only the MD-2, MD-4, MB-15 and AWACS cooling cart had specified maintainability numerics called out. The specified numerics were:

EQUIPMENT	MTTR(HOURS)	MMHOH	MEAN MAN HOURS TO REPAIR (HOURS)
AWACS COOLING CART	2.5	0.10	--
MD-2	0.5	--	1.0
MD-4	0.5	--	1.0
MB-15	0.5	--	--

The specifications did not require a predicted value and the specified value was usually demonstrated during the Preproduction Tests.

The review of the IPT reports (ref 1 to 16) disclosed that eleven of the sixteen test reports included maintainability test requirements. These requirements are:

EQUIPMENT	REF	MTTR(HOURS)	MR	A_a	Mct	MTBPM(HOURS)
MEP-115A	1	--	--	--	--	--
36K BTU/HR AC	2	--	--	--	--	--
12K BTU/HR AC	3	--	--	0.95	--	--
18K BTU/HR AC	4	--	--	--	--	--
AN/TTC-39	5	0.25	--	0.999	--	--
36K BTU/HR AC	6	--	--	0.95	--	--
18K BTU/HR AC	7	--	--	0.95	--	--
60K BTU/HR AC	8	--	--	0.95	--	--
100KW 60HZ EG	9	--	--	0.95	--	--
9K BTU/HR AC	10	--	--	0.95	--	--
MEP-017A	11	--	--	0.85	--	--
10KW 60HZ EG	12	--	--	--	--	--
5KW 60HZ EG	13	--	--	0.85	--	--
18K BTU/HR AC	14	--	--	--	--	--
18K BTU/HR AC	15	--	--	0.95	--	--
9K BTU/HR AC	16	--	0.03	--	--	250

TABLE 4.1-4: MAINTAINABILITY REQUIREMENTS

SPECIFICATION/STANDARD	PARA	MAINTAINABILITY REQUIREMENT
MIL-STD-633E-27	--	None
MIL-G-38441C (USAF)	4.4.2.1	PreProduction Testing: All failures, servicing, adjustments, maintenance, and irregular functioning shall be identified by accumulated operating time, cycles, miles, or position in the test procedure, as appropriate. Test conditions at the time of the events identified shall be recorded. These data are to be included as an appendix to the test report.
	4.3.11	The valve clearance, oil filter and air filter may be inspected at the completion of each 100 hours of operation. No adjustments shall be made. The oil system shall be drained and refilled with new oil at the start of the preproduction tests and at the completion of each 100 hours of operation. Oil may be added at intervals of 30 hours.
MIL-G-52889B	3.7	Maintenance ratio shall not be more than 0.04. Preventative maintenance schedule given for endurance test (Table II). Maintenance ratio measured during Reliability Test.
MIL-G-21480(AER)	--	None
MIL-G-6162B	3.4.4	Maintainability - Careful attention shall be given in the design to provide for ease of inspection, testing, disassembly, maintenance, repair and reassembly, preferably without the need for special tools or fixtures. Machine component parts shall be as fool proof as possible to avoid incorrect assembly which would result in damage or malfunction or involve safety of flight.
MIL-G-28670	3.4.3	Operating test gives preventative maintenance schedule (Table 1). No corrective maintenance permitted.

TABLE 4.1-4: MAINTAINABILITY REQUIREMENTS (CONT'D)

SPECIFICATION/STANDARD	PARA	MAINTAINABILITY REQUIREMENT
	3.6.2	Maintainability. The set shall operate as specified herein with only the maintenance authorized by the maintenance literature. All assemblies, installed attachments, wiring, and tubing shall be accessible for servicing, repair, and replacement without removal of other major assemblies and other installed attachments. Covers, safety guards, and plates which must be removed for component adjustment, repair, replacement, or maintenance shall be equipped with quick-disconnect fastenings. Dimensions of hand access openings shall be in accordance with MIL-STD-1472. All fuel, lubricant, and liquid reservoirs shall be piped to drain in accordance with 3.3.5. Each maintenance assembly or disassembly operation shall be accomplished with common tools and special tools furnished with the set.
	3.6.3	Mean preventive maintenance time. The mean preventive maintenance time to check, fill, adjust, clean, or replace (as appropriate), the item or system, shall not exceed 1.4 man hours. The need for preventive maintenance shall not occur more often than the intervals listed in Table I.
MIL-G-52732	--	Preventative Maintenance Schedules given in slash sheets.
MIL-A-52767B	3.2.0.1	Maintenance Ratio. The air conditioners shall have a maintenance ratio of not more than 0.03 when tested as specified in 4.6.3.25. Maintenance ratio is defined as the ratio of the total active maintenance man-hours required (scheduled and unscheduled) to the total operating time. Man-hours for repair of replaced components and scheduled before and after operational checks are excluded. A maintenance schedule shall be furnished prior to the start of testing. Not more than 25 percent of repairs shall require maintenance at the general support level.

TABLE 4.1-4: MAINTAINABILITY REQUIREMENTS (CONT'D)

SPECIFICATION/STANDARD	PARA	MAINTAINABILITY REQUIREMENT
	3.20.2	Scheduled Maintenance. The air conditioners shall not require scheduled maintenance more often than every 250 hours of operation when tested as specified in 4.6.3.25. Scheduled maintenance shall not be required at any level higher than organizational maintenance.
	4.6.3.25	Maintenance evaluation. The maintenance ratio shall be computed during initial production testing. All maintenance actions required during initial production testing shall be assessed to determine conformance to 3.20. Non conformance to 3.20 shall constitute failure of this test.
MIL-G-26727D (USAF)	3.8.2	Maintainability. Maintainability requirements shall be in accordance with MIL-STD-470 and MIL-STD-471.
	3.8.3	Mean-Time-To-Repair. The mean-time-to-repair for corrective maintenance shall not be more than 2 hours.
	4.4.2.1	Maintainence information required to be submitted as part of the Preproduction Test report.

The most widely used maintainability criteria specified was A_a (10 out of 11). MTTR and MR were each specified once. A quantitative preventative maintenance requirement, Mean Time Between Preventative Maintainence (MTBPM), was called out once.

A review of the AN/TSC-60(V), AN/TSQ-XX and AWACS AAA reports revealed the following maintainability information:

SYSTEM	MAINTAINABILITY INFORMATION
AN/TSC-60(V)	System requirement specified was MTTR; however, the ECU and power generation (conversion) equipments did not appear to be included in the requirement. The power distribution network was included, but it was not broken out so that it could be easily evaluated.
AN/TSQ-XX	System requirements specified were Mct and Mct $_{max}$ (95%). These requirements were broken out to both the module level and for both Contractor Furnished Equipment (CFE) and Government Furnished Equipment (GFE). Availability (A_a) was also called out at the system level. Maintainability Prediction was by MIL-HDBK-472, Procedure 3. Maintainability Test was by MIL-STD-471 Notice 1, Method 2. The predicted M values for the GFE equipments were based on estimates of MTBF taken from Government procurement specifications for the GFE equipment. Where these data were not available, the estimates were based on system's test data.
E-3A AWACS	Requirements given for Flight Line MTTR and M_{max} and total MMH/FH. The requirements were allocated to the air vehicle and air vehicle equipments. Predictions were made for the air vehicle equipments for the following numerics:

Base Level

Organizational	MTTR
Organizational	M_{max}
Organizational	MMH/FH
Intermediate	MMH/FH
ORG & INTER	MMH/FH

Depot Level

MMH/FH

Total

MMH/FH

Predictions were based on achieved numerics by similar equipments. Demonstrated was obtained by flight tests. The AWACS cooling cart had MTTR and MMHOH specified.

The specification of maintainability requirements for ancillary E/M equipments is inconsistant for both the equipment specifications and when the E/M equipments are incorporated as part of a system. When a maintainability numeric is specified, it is most often A_a, and it is demonstrated by collecting data during other qualification tests. The data collected on the system level maintainability numerics indicated that the ancillary E/M equipments may or may not be included when the system level numeric is allocated to the equipment level, and they may or may not be included in the maintainability demonstration. If they are included in the maintainability demonstration, the maintainability demonstration is usually conducted concurrently with other qualification tests.

Maintainability predictions of ancillary E/M equipments appear to be made from test or field experience data on similar equipments.

Twelve methods for demonstrating maintainability are called out in MIL-STD-471A Notice 1. Methods 1 through 4 and 7 through 11 allow for the use of natural occurring failures or the use of simulated failures, and methods 5 and 6 allow for the use of natural occurring failures. There are arguments against the use of both simulated failures and naturally occurring failures. Those against simulated failures usually center around the fact that they may not duplicate actual real world failure symptoms, and the repair personnel are anticipating the failure and have tools and maintenance documents close at hand; therefore, the repair times are not realistic. The arguments against the use of naturally occurring failures centers around the fact that the sample size may be negligible and that the repair of critical items or long repair time items may not be demonstrated.

One method of resolving these concerns would be to allow the use of natural occurring failures during other qualification tests, but specify a minimum sample size. Simulated failures would be used to make up the difference between what occurred naturally and the minimum requirement. Care would have to be taken to select the correct test method for the simulation test. Methods 1-A, 2, 4 and 8 are based on the assumption that the repair times are lognormally distribution. An analysis of the A/E24U-8 repair times showed that the repair times were not lognormally distributed, but rather that they followed the Weibull distribution with a Beta (β) of 0.75. Care should also be taken in the task selection since the procedures used to select the tasks are based on a constant failure rate which may not be valid for electromechanical parts.

The method of specifying maintainability given for the AN/TSQ equipments appears to be a good method when the ancillary E/M equipments are furnished as GFE. The M numeric was allocated to the equipment, but it was not part of the demonstration requirement. The allocated and predicted data were included in the AAA reports so that the impact of these equipments on the system could be readily ascertained. On thing that should be specified, however, is the inclusion of all E/M equipments, for instance, both engine generators and motor generators in the assessments. For systems such as the E-3A AWACS, the AGE equipment should be included in the allocations if a true estimate of the required system logistics is desired.

The procedure of basing the maintainability prediction of the E/M equipments on historical data from similar systems is at present the most acceptable method since the present methods called out in MIL-HDBK-472 are based on the concept of an average failure rate and either normally or lognormally distributed repair times.

5.0 SUMMARY OF RESULTS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Results and Conclusions

A primary objective of this study was to investigate the R/M impact of ancillary electromechanical (E/M) equipments on the USAF C^3I Systems they support. Two methods of assessing the impact were used. One method compared the individual E/M achieved R/M numeric with what was specified in the equipment specification, or, in the absence of a specified value, with a demonstrated value that was derived from the results of similar equipments during Initial Production Tests (IPTs). The objective of the method was to determine if the achieved R/M numeric was better or worse than what was specified or what would be anticipated based on the results of the IPTs. For the purpose of determining a result, an adverse impact was defined as when the R/M numeric did not meet the specified or IPT result. The results of this assessment were:

EQUIPMENT	NUMERIC RELIABILITY	NUMERIC MAINTAINABILITY
GROUND C^3I SYSTEM		
ECU	BETTER	WORSE
POWER DISTRIBUTION	WORSE	WORSE
ENGINE GENERATOR	WORSE	WORSE
MOTOR GENERATOR	BETTER	WORSE
AIRBORNE C^3I SYSTEM		
AIRCRAFT POWER GENERATION (PG)	WORSE	BETTER
AIRCRAFT POWER DISTRIBUTION (PD)	WORSE	BETTER
AIRCRAFT ECU	WORSE	WORSE
AIR VEHICLE LESS PG, PD, ECU AND ELECTRONICS	BETTER	WORSE
MEP-116A	WORSE	WORSE

The results show that in general the achieved R/M numerics are not as good as what was anticipated.

The second method compared the percent of achieved system R/M associated with the ancillary E/M equipment with the percentage called out as a requirement in the procurement specification, or what was specified or demonstrated on similar type equipments during IPTs. The objective of this method was to determine if the achieved R/M percent of achieved system R/M was higher than what was anticipated during system development. For the purpose of determining a result, an adverse impact was defined as when the achieved R/M percentage was higher than the percentage generated from the specified R/M numerics. The results of this assessment were:

EQUIPMENT	RELIABILITY	MAINTAINABILITY	AVAILABILITY
		NUMERIC	
AN/TSC-60(V)-1			
POWER DISTRIBUTION NETWORK	BETTER	BETTER	BETTER
ECU	BETTER	BETTER	BETTER
POWER GENERATION	WORSE	WORSE	WORSE
POWER CONVERSION	WORSE	WORSE	WORSE
AN/TSC-60(V)-2			
POWER DISTRIBUTION NETWORK	WORSE	SAME	BETTER
ECU	BETTER	BETTER	BETTER
POWER GENERATION	WORSE	WORSE	WORSE
POWER CONVERSION	BETTER	WORSE	WORSE
AN/TSC-60(V)-3			
POWER DISTRIBUTION NETWORK	WORSE	WORSE	BETTER
ECU	BETTER	BETTER	BETTER
POWER GENERATION	WORSE	WORSE	WORSE
POWER CONVERSION	WORSE	WORSE	WORSE
AN/TSQ-91			
POWER DISTRIBUTION NETWORK	WORSE	BETTER(1)	BETTER(1)
ECU	BETTER	BETTER	BETTER
POWER GENERATION	WORSE	WORSE	WORSE
POWER CONVERSION	WORSE	WORSE	WORSE
AN/TSQ-92			
POWER DISTRIBUTION NETWORK	WORSE	BETTER	BETTER
ECU	BETTER	BETTER	BETTER
POWER GENERATION	WORSE	WORSE	WORSE
POWER CONVERSION	WORSE	WORSE	WORSE
AN/TSQ-93			
POWER DISTRIBUTION NETWORK	WORSE	WORSE	WORSE
ECU	BETTER	BETTER	BETTER
POWER GENERATION	WORSE	WORSE	WORSE
POWER CONVERSION	WORSE	WORSE	WORSE
E-3A AWACS			
POWER GENERATION	BETTER	-	-
POWER DISTRIBUTION	BETTER	-	-
POWER GENERATION & DISTRIBUITON	WORSE	BETTER	-
ECU	WORSE	WORSE	-
AIR FRAME	WORSE	BETTER	-

NOTES: 1) Results of the TAC BLIS. The results of the D056B5503 report indicate that the achieved numeric is worse.

The analyses led to the following conclusions:

1. The power distribution equipment achieved R/M numeric may or may not be worse than what was anticipated depending on the system. The percent of the achieved system R/M numeric attributed to the power distribution equipment is relatively low (worst case result approximately 2% of the system failures).

2. The achieved R/M numerics for the ECU equipment were consistently better than what was specified.

3. The Power Generation and Power Conversion achieved R/M numerics are consistently worse that what was specified.

4. The results and conclusions drawn from the analyses are biased because data were extracted from different data sources. The achieved R/M numerics for the power generation and power conversion equipment were derived from data collected during the second survey. The second survey data are well documented and there is reasonable assurance that all of the maintenance events were recorded. The data extracted from the TAC BLIS and D056B5503 reports may or may not be recorded with as much rigor. An estimate of the achieved ECU MTBM was derived from the Second Survey data and from all of the system D056B5503 reports. The MTBM estimates are:

	MTBM (HOURS)	
	SECOND SURVEY	D056B5503
Point Estimate	1757	3792
Lower 90% Confidence Interval Limit	1400	3407
Upper 90% Confidence Interval Limit	2232	4231

A comparison of the MTBMs shows that the achieved MTBM reported on the D056B5503 reports is considerably higher than what was reported during the Second Survey. Therefore, the achieved MTBM that was used for the power generation and conversion equipments may be lower than if it had been reported on the D056B5503 reports, and, consequently, the percentage calculations for the power equipment may be pessimistically biased. The extent of the bias is unknown.

5. The analyses compared inherent R/M numerics with field experience data. The R/M numerics generated from the MDS data is in general always worse than what was specified. This bias can be traced directly to the difference in the definitions of the specified (MTBF, MTTR) and field experience (MTBM, Aa) R/M numerics. The specified R numeric includes only inherent part failures; the achieved R numeric includes design, workmanship and part failures. The specified M numeric considers optimum maintenance personnel and repair conditions (correct tools,

spares immediately on hand, etc.); the achieved M numeric can only hope to approach these conditions.

6. The study was restricted by the fact that in general R/M numerics are not specified for E/M equipments, and pseudo R/M numerics had to be derived.

Data were collected from a variety of sources including: Commercial Equipment Manufacturers, USAF Unit Failure Logs, USAF Maintenance Data Systems, US Army Test Reports, an USAF Unit Survey (Survey One), US Army Maintenance Data System, and an USAF Captive Sample Data Collection Effort (Survey Two). An evaluation of these sources led to the following conclusions:

1. Engine generators, motor generators and stand-alone ECUs are shared between systems within an USAF unit and are frequently lent to other USAF units. With permanently mounted ECUs, if a unit possesses a spare ECU, the spare is frequently installed in place of a failed ECU and the failed ECU then becomes the spare. Therefore it is impossible to track specific system-ancillary-E/M combinations with the present USAF data collection system.

2. Engine generators and motor generators are not included in the system WUC manual; therefore, the failure occurrences and maintenance activities of the power equipment can not be linked directly to a specific system with the present USAF data collection system. ECU and internal power distribution equipments are included in the WUC manual and can be tracked with the system.

3. The percentage of maintenance events that are classified as failures in the D056B5503 reports, AFALO Manual 800-4 and the E-3A AWACS R&M Index was considerably higher (61.5 - 94.5%) than what other sources indicated (2-43%) as being the percentage of maintenance events that are actually failures. This indicated that either the algorithms or the codes that are used to classify a failure are wrong or that the codes are not being used properly by the maintenance personnel, or that the estimates provided by references 42 and 51 are wrong (23 and 2-43% respectively).

4. The D056B5503 reports showed that none of the TSC-60(V)-1 and TSQ-91 power distribution failures resulted in system downtime. The reports also showed that none of the ECU failures on the TSC-60(V)-1 system resulted in system downtime and only 3.8% of the ECU failures on the TSQ-91 resulted in system downtime. The data collected during the second survey also showed that 4% of the ECU failures resulted in system downtime. These data coupled with the fact that the ECUs did not fail as frequently as anticipated would indicate that the ECUs do not have an adverse impact on system availability.

5. The AFTO 95 Forms, depot repair activities and the Supply Lists (ISSL) should not be used to derive estimates of equipment reliability because the AFTO 95 forms only list a small percentage of the repair actions

actually performed on the equipment, the depot may or may not be in the repair loop, and a large number of repair parts are procured locally.

6. The estimate of the number of ground operating hours for each flying hour (0.5) used by the Air Force does not agree with the estimate provided by using personnel at Tinker AFB (3.0); therefore, if the Tinker AFB estimate is accurate, the MTBF estimates given in AFALD 800-4 are unrealistically low.

7. Accurate estimates of operating times can only be obtained through a special data collection effort on selected equipments such as the second survey effort conducted for this study. Accurate operating time estimates are not currently being used for the USAF MDS reports; therefore, the R/M numerics presented in them are inaccurate. This would not be a problem if the data in the reports were used solely to gage the R/M impact of a sub system on a system since the operating time errors are the same for both; however, the data are used to make comparisons with specified R/M numerics and with other systems where the error may or may not be the same.

8. The USAF MDS data sources serve the purpose for which they were intended (logistics); they can be used to identify maintainability and reliability problems on Air Force equipment in a relative sense; however, they are inadequate for deriving R/M numerics because of missing, incorrect and incomplete data.

Information was collected pertaining to the specified, predicted and demonstrated R/M at both the equipment and system level. This information was collected from a variety of sources including: equipment and system manufacturers, military specifications and standards, and test reports. An evaluation of these sources led to the following conclusions:

1. The exponential distribution is usually assumed for Reliability Demonstration tests. This assumption may or may not be right for a particular equipment. A more realistic method of testing would be to use a Weibull type test plan similar to the one developed during this study.

2. The specification of R/M numerics at the equipment level is at best haphazard. The most widely used R numerics are reliability and minimum acceptable MTBF. The most widely used maintainability numeric was availability. Standardization is needed so that valid comparisons can be made between equipments.

3. The inclusion of the ancillary E/M equipment in the system level R/M allocations and assessments is inconsistent when the equipment is furnished as GFE. They need to be included to make an accurate system level R/M assessment.

4. The preventative maintenance criteria, if they were called out at all in the specification, were in general spelled out in subjective terms. Data were not available to compare specified to achieved.

5.2 Recommendations

The WUC manuals for each system should be revised to include a provision for the power generation equipment so that the USAF MDS can be used to provide an estimate of the power generation equipment impact on system R/M. A single WUC entry would be required to determine the impact that the power equipment has on system R/M. A three or four level indentured WUC would be required to determine problem areas within the power equipment.

The procedures governing the use of the AFTO 95 forms should be revised so that it is mandatory that Elapsed Time Meter (ETM) readings are recorded at least yearly and every time the ETM is changed.

A study should be instituted to develop accurate operating time estimates for both ground and airborne USAF systems and equipments.

The reliability demonstration test plans that are based on the exponential distribution may or may not be the most accurate or the most economical method of demonstrating the reliability of E/M equipments. A study should be instituted to investigate in greater depth other methods such as the Weibull Test Plan developed during this study.

It is recommended that whenever system or equipment unreliability becomes a significant logistic support problem to the logisticians or a major dependability/sustainability concern for the operations that:

1. The Air Force MDS and the data products available from it (see RADC-TR-81-267, pg 15, Note 1) be used for exactly as it was intended --a first indenture indicator of where the major problems exist.

2. A period of operational reliability reassessment be undertaken jointly by the development/acquisition (AFSC) logistic support (AFLC) organizations and the operational command (SAC/TAC). The objective of the reassessment would be to obtain from on-site observation and data recording, accurate failure and failure rate information as a function of true operating times. From this data, the significant failure items

could thus be isolated and an in-depth cause of failure investigation and corrective action programs undertaken using the investigative techniques developed under the Air Force's Rivet Gyro Program.

3. The RADC Reliability Analysis Center be utilized as a "feed forward" information center for data derived from the reassessment programs.

4. The RADC become the advocacy organization for such changes as may be required in Air Force policies, practices, and procedures whose deficiencies consistently contribute to system and equipment operational reliability problems.

An effort should be instituted by DoD to standardize the specifications of R/M numerics in the equipment specifications. The requirements should include a reliability, corrective maintenance and preventative maintenance quantitative numeric.

The procuring activity should specify that the GFE be included in all system level R/M allocations and assessments so that accurate R/M assessments are available for decision purposes.

A study was recently instituted by RADC that will derive factors to account for the differences between specified R/M numerics and the R/M numerics derived from field experience data. Ancillary E/M equipments should be included in the study.

REFERENCES

REFERENCE No.	TITLE
1	AFCS Pamphlet 100-98, AFCS Mobile/Transportable Communications and Supporting Equipment Directory, August, 1977.
2	TAC Pamphlet 55-43, Tactical Air Control System Equipment, May, 1981.
3	U.S. Army Aberdeen Proving Ground, Final Letter Report Initial Production Test of Generator Set, 60KW, 400HZ, ADB022310, September, 1977.
4	U.S. Army Aberdeen Proving Ground, Final Letter Report of Initial Production Test of Air Conditioner, 36,000 BTU/HR, Electric Motor Powered, 60HZ, 208 Volts, 3 phase, AD878388, November, 1970.
5	U.S. Army Aberdeen Proving Ground, Initial Production Test of Air Conditioner, 18,000 BTU/HR, Compact Vertical, 208 Volt, 3 phase, 400 HZ, Final Report, TECOM Project No. 7-EG-175-018-013, Report No. APG-MT-4375, November, 1973.
6	U.S. Army Aberdeen Proving Ground, Final Letter Report, Reconditioning Test of Air Conditioner, 18,000 BTUH, Multipackage, ADB031323, September, 1978.
7	U.S. Army Aberdeen Proving Ground, TECOM Independent Evaluation Report Development Test II for the AN/TTC-39()(V) Circuit Switch (CS), ADB046938, May, 1980.
8	U.S. Army Aberdeen Proving Ground, Initial Production Test of Air Conditioners, Compact Vertical, 36,000 - BTU/HR, 50/60 HZ Class I and 400 HZ, Class 2 Final Report, AD879643L, January, 1971.
9	U.S. Army Aberdeen Proving Ground, Initial Production Test of Air Conditioner, 18,000 BTU/HR, 60 HZ, 5-Stack, Base - Mounted Final Report, AD904959, August, 1972.
10	U.S. Army Aberdeen Proving Ground, Initial Production Test of Air Conditioner, 60,000 BTU/HR, Gasoline-Engine-Driven, Self-Contained, Skid-Mounted Final Report, AD908047L, January, 1973.
11	U.S. Army Aberdeen Proving Ground, Initial Production Test of Generator Set, 100-KW, 50/60 HZ, DED, General Purpose Final Report, AD878918L, December, 1970.
12	U.S. Army Aberdeen Proving Ground, Initial Production Test of Air Conditioner, 9000 BTU/HR, Horizontal Compact, Class 1, Class 2, Class 3, and Class 4 Final Report, AD915390, November, 1973.

REFERENCES (CONT'D)

REFERENCE No.	TITLE
13	U.S. Army Aberdeen Proving Ground, Initial Production Test of Generator Set, 5-KW, 60-Hertz, GED, Air-cooled, Portable, Tubular-Frame, Skid-Mounted Final Report, AD893325L, February, 1972.
14	U.S. Army Aberdeen Proving Ground, Final Report Development Test III of Generator Set 10-KW, 60-Hertz, Air-cooled. Diesel-Engine-Driven, ADB016354, September, 1976.
15	U.S. Army Aberdeen Proving Ground, Initial Production Test of Generator Set, 5-KW, 60-HZ, MEP Model 017A Final Report, AD919277, April, 1974.
16	U.S. Army Aberdeen Proving Ground, Final Letter Report Initial Production Test of Air Conditioner, Horizontal, Compact 18,000 BTU/HR 208 Volt, 400 HZ, ADB039145L, June, 1979.
17	U.S. Army Aberdeen Proving Ground, Final Letter Report Initial Production Test of Air Conditioner, 18,000 BTU/HR, Compact, Horizontal, Type II, Class 2, ADB0223116, October, 1977.
18	U.S. Army Aberdeen Proving Ground, Final Report Initial Production Test of Air Conditoner, 9,000 BTUH Compact Vertical, ADB041335, October, 1979.
19	U.S. Army Aberdeen Proving Ground, Initial Production Test of Air Conditioners, Compact Vertical, 60,000 BTU/HR, 50/60HZ, Class 1, and 400HZ, Class 2, Final Report, AD879789L, January, 1971.
20	ARINC Research Corporation, CGN-42 HM & E Equipment R & M Study, ADA064699, January, 1979.
21	U.S. Army Aberbeen Proving Ground, U.S. Army Test and Evaluation Command System Engineering Test Operations Procedure - "Heating Equipment" AD742517, April, 1972.
22	Gulton Industries, Inc., Development Program For 3.0KW Inverter, ADA068433, January, 1979.
23	U.S. Air Force, Operational Test and Evaluation Final Report, C-5 Single Air Conditioning Pack Capability, ADB006016, August, 1975.
24	U.S. Navy Civil Engineering Laboratory, Compilation of Operational Performance Records Uninterruptible Electrical Power Supply Equipment, AD882819L, November, 1965.
25	Philips Laboratories, Cryogenic Refrigerator For HALO Program Quarterly Technical Report, ADB02305L, October, 1977.

REFERENCES (CONT'D)

REFERENCE No.	TITLE
26	Varo, Inc., Reliability Study of Power Conditioning Ancillary Items, Final Report, AD723433, April, 1971.
27	Rockwell International, Nonnuclear System Response Analysis Vulnerability Data, Environmental Control Subsystem (ECS), ADB027313, July, 1975.
28	Collins Radio Company, Production Reliability Test II Evaluation Report (Final), Contract FI9628-68-C-0164 AN/TSC-60(V) Program, September 29, 1972.
29	Collins Radio Company, Reliability Test and Evaluation Report (Final), Contract F1962B-68-C-0164 AN/TSC-60(V) Program, July 27, 1971.
30	Collins Radio Company, Final Maintainability/Reliability Status Report R&M Report For AN/TSC-60(V)1, AN/TSC-60V()2, and AN/TSC-60(V)3, July 21, 1971.
31	Hughes Aircraft Company, CDRL ITEMS 62/75 CDRL 62 Reliability Test and Evaluation CDRL Category I Test Procedure and results 407L Operations Centers, December 23, 1969.
32	Hughes Aircraft Company, CDRL ITEM 58 Reliability/Maintainability All ocation, Assessment and Analysis Report, September 15, 1968.
33	The Boeing Company, R-103-1 Report, Reliability and Maintainability Allocations, Assessments and Analysis - Reliability - Air Vehicle, April 16, 1973.
34	The Boeing Company, R-1-3-1 Report, Reliability and Maintainability Allocations, Assessments and Analysis - Reliability - Air Vehicle, April 16, 1973.
35	The Boeing Company, E-3A Reliability/Maintainability Program Status Report, June, 1980 to July, 1981.
36	AFLCR 66-15, Product Performance, August, 1974.
37	OC-ALC Concepts and Cost Group Logistics Analysis Section, Reliability and Maintainability Index, E-3A, Jim Mosley, July, 1979 to June, 1980.
38	AFALD 800-4, Aircraft Historical Reliability and Maintainability Data, January, 1981.
39	USAF Tactical Air Command, Production Analysis Summary September 30, 1981.

REFERENCES (CONT'D)

REFERENCE No.	TITLE
40	Headquarters Sacramento Air Logistics Center, ISSLs 19F00082 and 19F00114, AE24U-8 and MD-4 Generator Sets, Requested 23 July, 1981.
41	AFTO 00-20-2, Maintenance Data Collection System, November, 1981.
42	Orlansky, J. and String, J., The Performance of Maintenance Technicians on the Job, Institute For Defense Analyses, Science and Technology Division, IDA Paper P-1597, August, 1981.
43	IIT Research Institute, Least Cost Test Profile Final Report, Contract No. 30602-80-C-0263, November, 1981.
44	Natrella, Mary M., Experimental Statistics, National Bureau of Standards Handbook 91, August, 1963.
45	MIL-A-38229D, Military Specification, Air Conditioners, Lightweight, Compact, Military, General Requirements For, March, 1970.
46	MIL-G-83380, Military Specification, Generator Sets, Gas Turbine Engine Driven, 30 and 60 KW, 400 Hertz, February, 1979.
47	MIL-M-4820E, Military Specification, Motor-Generator, Skid Mounted MD-4, July, 1979.
48	MIL-M-4820E, Military Specification, Motor-Generator, Skid Mounted Type MD-2, July, 1979.
49	MIL-G-2627D, Military Specification, Generator Sets, Diesel Engine, 15KW thru 150KW, 50/60 Hertz, Type I (Tactical), Class 2 (Utility), June, 1974.
50	MIL-G-52884, Military Specification, Generator Sets, Diesel Engine Driven, 15 thru 200 Kilowatts 50/60 and 400 Hertz, Type I (Tactical), Class 2 (Utility), March, 1971.
51	Huss, K., Electronic Equipment Reliability Data, Reliability Analysis Center, Report EERD-1, Fall, 1980.
52	AFALD 800-4 Aircraft Historical Reliability and Maintainability Data, January, 1981.
53	MIL-G-52884/12, Generator Set, Diesel Engine Driven, 100 Kilowatt, 400 Hertz, Precise, (Tactical), Specification For, 23 November, 1976.
54	USAF Technical Manual T.O. IE-3A-06, Aircraft Work Unit Code Manual USAF Series E-3A Aircraft, August 1, 1980.

REFERENCES (CONT'D)

REFERENCE No.	TITLE
55	Kremp, B.F., Kimball, E.W., Revision of Environmental Factors For MIL-HDBK-217, RADC-TR-80-299, September, 1980. (A091837)
56	Johnson, L.G., The Statistical Treatment of Fatigue Experiments, Elsevier, 1964.

BIBLIOGRAPHY

AFALD 800-4, Aircraft Historical Reliability and Maintainability Data, January, 1981.

AFCS Pamphlet 100-98, AFCS Mobile/Transportable Communications and Supporting Equipment Directory, August, 1977.

AFLCR 66-15, Product Performance, August, 1974.

AFR 80-5, Air Force Reliability and Maintainability Program, Change 1, July 1979.

AFTO 00-20-2, Maintenance Data System, November, 1981.

ARINC Research Corporation, CGN-42 HM&E Equipment R&M Study, ADA 064699, January, 1979.

The Boeing Company, E-3A Reliability/Maintainability Program Status Report, June, 1980 to July, 1981.

The Boeing Company, Maintainability of Air Force Ground Systems Nonelectronic Equipment/Devices, RADC-TR-72-251, AD905566L, October, 1972.

The Boeing Company, R-103-1 Report, Reliability and Maintainability Allocations, Assessments, and Analysis-Maintainability-Air Vehicle, April 16, 1973.

The Boeing Company, R-103-1 Report, Reliability and Maintainability Allocations, Assessments and Analysis-Reliability-Air Vehicle, April 16, 1973.

Collins Radio Company, Final Maintainability/Reliability Status Reports, R&M Report For AN/TSC-60(V)-1, AN/TSC-60(V)-2, and AN/TSC-60(V)-3., July 21, 1971.

Collins Radio Company, Production Reliability Test II Evaluation Report (Final), Contract FI9628-68-C-0164, AN/TSC-60(V) Program, September 29, 1972.

Collins Radio Company, Reliability Test and Evaluation Report (Final), Contract F19628-68-C-0164, AN/TSC-60(V) Program July 27, 1971.

CP-351100-A, Prime Item Development Specification, CRC/CRP Operations Center for the TACS/TADS ART Configuration AN/TSQ-91(V) ( ), Cl Number 201000 B, March, 1974.

Gulton Industries, Inc., Development Program For 3.0KW Inverter, ADA068433, January, 1979.

Headquarters Sacramento Air Logistics Center, ISSLs 19F00082 and 19F00114, AE24U-8 and MD-4 Generator Sets, Requested 23 July 1981.

Hughes Aircraft Company, CDRL Item A035, Reliability/Maintainability Allocation, Assessment and Analysis Report for the 407L ART Improvement Program, August, 1974.

Hughes Aircraft Company, CDRL ITEM: 58, Reliability/Maintainability Allocation, Assessment and Analysis Report, September 15, 1968.

Hughes Aircraft Company, CDRL ITEM: 62/75 CDRL 62, Reliability Test and Evaluation, CDRL CATEGORY I TEST Procedure and Results, 407L Operations Centers, December 23, 1969.

IIT Research Institute, Least Cost Test Profile Final Report, Contract No. F30602-80-C-0263, November, 1981.

OC-ALC Concepts and Cost Group Logistics Aanlysis Section, Reliability and Maintainability Index, E-3A, Jim Mosley, July, 1979 to June, 1980.

Philips Laboratories, Cryogenic Refrigerator For HALO Program, Quarterly Technical Report, ADB02305L, October, 1977.

Rockwell International, Nonnuclear System Response Analysis Vulnerability Data, Environmental Control Subsystem (ECS), ADB027313, July, 1975.

TAC Pamphlet 55-43, Tactical Air Control System Equipment, May, 1981.

U.S. Air Force, Operational Test and Evaluation Final Report, C-5 Single Air Conditioning Pack Capability, ADB006016, August, 1975.

USAF Tactical Air Command, Production Analysis Summary, September 30, 1981.

U.S. Air Force Tactical Air Command, Production Analysis Summary, Ground Systems, September, 1981.

U.S. Air Force, Tactical Air Command, Production Analysis Summary, July, 1980.

U.S. Air Force Tactical Air Command, Production Analysis Summary, Ground Systems, November, 1981.

USAF Technical Manual T.O. IE-3A-06, Aircraft Work Unit Code Manual, USAF Series E-3A Aircraft, August 1, 1980.

USAF Technical Manual T031Z1-407-06, Depot, Intermediate and Organizational Maintenance Work Unit Code Manual, 407L Tactical Air Control System, June 24, 1981.

U.S. Army Aberdeen Proving Ground, Final Letter Report, Initial Production Test of Generator Set, 60KW, 400HZ, ADB022310, September, 1977.

U.S. Army Aberdeen Proving Ground, Final Letter Report of Initial Production Test of Air Conditioner, 36,000 BTU/HR, Electric Motor Powered, 60 HZ, 208 Volts, 3 Phase, AD878388, November, 1970.

U.S. Army Aberdeen Proving Ground, Final Letter Report, Reconditioning Test of Air Conditioner, 18,000 BTU, Multipackage, ADB031323, September, 1978.

U.S. Army Aberdeen Proving Ground, Final Report, Development Test III of Generator Set 10-KW, 60-Hertz, Air-cooled, Diesel-Engine-Driven, ADB016354, September, 1976.

U.S. Army Aberdeen Proving Ground, Final Letter Report, Initial Production Test of Air Conditioner, Horizontal, Compact 18,000 BTU/HR 208 Volt, 400 Hz, ADB039145L, June, 1979.

U.S. Army Aberdeen Proving Ground, Final Letter Report, Initial Production Test of Air Conditioner, 18,000 BTU/HR, Compact, Horizontal, Type II, Class 2, ADB022311L, October, 1977.

U.S. Army Aberdeen Proving Ground, Final Report, Initial Production Test of Air Conditioner, 9,000 BTUH Compact Vertical, ADB041335, October, 1979.

U.S. Army Aberdeen Proving Ground, Initial Production Test of Air Conditioner, 18,000 BTU/HR, Compact Vertical, 208 Volt, 3 phase, 400 Hz, Final Report, TECOM Project No. 7-EG-175-018-013, Report No. APG-MT-4375, November, 1973.

U.S. Army Aberdeen Proving Ground, Initial Production Test of Air Conditioners, Compact Vertical, 36,000-BTU/HR, 50/60 Hz, Class 1 and 400 Hz, Class 2 Final Report, AD879643L, January, 1971.

U.S. Army Aberdeen Proving Ground, Initial Production Test of Air Conditioner, 18,000 BTU/HR, 60 Hz, 5-Stack, Base-Mounted Final Report, AD904959, August, 1972.

U.S. Army Aberdeen Proving Ground, Initial Production Test of Air Conditioner, 60,000 BTU/HR, Gasoline-Engine-Driven, Self-Contained, Skid-Mounted Final Report, AD908047L, January, 1973.

U.S. Army Aberdeen Proving Ground, Initial Production Test of Generator Set, 100-KW, 50/60 Hz, DED, General Purpose, Final Report, AD878918L, December, 1970.

U.S. Army Aberdeen Proving Ground, Initial Production Test of Air Conditioners, Compact Vertical, 60,000 BTU/HR, 50/60 Hz, Class 1, and 400 Hz, Class 2, Final Report, AD879789L, January, 1971.

U.S. Army Aberdeen Proving Ground, Initial Production Test of Generator Set, 5-KW, 60-Hz, MEP Model 017A, Final Report, AD919277, April, 1974.

U.S. Army Aberdeen Proving Ground, Initial Production Test of Generator Set, 5-KW, 60-Hertz, GED Air-cooled, Portable, Tubular-Frame, Skid-Mounted, Final Report, AD893325L, February, 1972.

U.S. Army Aberdeen Proving Ground, Initial Production Test of Air Conditioner, 9000 BTU/HR, Horizontal Compact, Class 1, Class 2, Class 3, and Class 4, Final Report, AD915390, November, 1973.

BIBLIOGRAPHY (CONT'D)

U.S. Army Aberdeen Proving Ground, U.S. Army Test and Evaluation Command System Engineering Test Operations Procedure - "Heating Equipment", AD742517, April, 1972.

U.S. Army Materiel Command, Engineering Design Handbook, Environmental Series, Part One, Basic Environmental Concepts, AD-784999, July, 1974.

U.S. Army Materiel Command, Engineering Design Handbook: Electrical Systems, AD-783697, June, 1974.

U.S. Army Materiel Command, Engineering Design Handbook, Criteria for Environmental Control of Mobile Systems, AD889588L, September, 1971.

U.S. Army, Sample Data Collection, 5, 15, 30KW Generator, SDC Logistics Analysis Management Quarterly Summary, April, 1981.

U.S. Army, Sample Data Collection, 5, 15, 30KW Generator, SDC Logistics Analysis Management Quarterly Summary, January, 1981.

U.S. Army Aberdeen Proving Ground, TECOM Independent Evaluation Report, Development Test II for the AN/TTC-39( ) (V) Circuit Switch (CS), ADB046938, May, 1980.

U.S. Navy Civil Engineering Laboratory, Compilation of Operational Performance Records, Uninterruptible Electrical Power Supply Equipment, AD882819L, November, 1965.

Varo, Inc., Reliability Study of Power Conditioning Ancillary Items, Final Report, AD723433, April, 1971.

Fiorentino, E., The Use of Air Force Field Maintenance Data for R&M Assessments of Ground Electronic Systems, RADC-TR-79-103, April, 1979.

Huss, K., Electronic Equipment Reliability Data, Reliability Analysis Center, Report EERD-1, Fall, 1980.

Ireson, W. G., Reliability Handbook, McGraw-Hill, 1966.

Johnson, L. G., The Statistical Treatment of Fatigue Experiments, Elsevier, 1964.

Kremp, B. F., Kimball, E. W., Revision Of Environmental Factors for MIL-HDBK-217, RADC-TR-80-299, September, 1980.

Natrella, Mary, M., Experimental Statistics, National Bureau of Standards Handbook 91, August, 1963.

Orlansky, J. and String, J., The Performance of Maintenance Technicians on the Job, Institute For Defense Analyses, Science and Technology Division, IDA Paper P-1597, August, 1981.

BIBLIOGRAPHY (CONT'D)

Short, J. E., An Assessment of the Magnitude of Electromechanical Failures Occurring Within Air Force Command, Control, Communications, and Intelligence (C^3I) Systems, Draft Final Technical Report, June, 1981.

MIL-A-38269E, Military Specification, Air Conditioner, A/E32C-17, February, 1975.

MIL-A-38339D, Military Specification, Air Conditioners, Lightweight, Compact, Military, General Requirements For, March, 1970.

MIL-A-38340C, Military Specification, Air Conditioner, A/E32C-18, November, 1977.

MIL-A-38345D, Military Specification, Air Conditioner, A/E32C-24, February, 1970.

MIL-A-38346D, Military Specification, Air Conditioner, A/E32C-25, December, 1978.

MIL-A-38347D, Military Specification, Air Conditioner, A/E32C-26, February, 1970.

MIL-A-38348C, Military Specification, Air Conditioner, A/E32C-27, January, 1970.

MIL-A-52767B, Military Specification, Air Conditioners: Vertical and Horizontal, Compact, September, 1979.

MIL-G-26727D, Military Specification, Generator Sets, Diesel Engine, 15KW through 150KW, 50/60 Hertz, Type I (Tactical), Class 2 (Utility), June, 1979.

MIL-G-38195C, Military Specification, Generator Set, Gas Turbine Engine, 60KW, 400 Hertz, General Purpose, July, 1978.

MIL-G-38441C, Military Specification, Generator Sets, Diesel Engine EMU-19/U, EMU-20/U, EMU-21/U, EMU-23/U, EMU-24/U, 400 Cycle Output, Multi-Installation, August, 1971.

MIL-G-52884, Military Specification, Generator Sets, Diesel Engine Driven, 15 through 200 kilowatts, 50/60 and 400 Hertz (Tactical) General Specification for, March, 1981.

MIL-G-52884/12, Generator Set, Diesel Engine Driven, 100 Kilowatt, 400 Hertz, Precise, (Tactical), Specification for, 23 November 1976.

MIL-G-52886A, Military Specification, Generator Set, Diesel Engine, Trailer Mounted, 60KW, 400 Hertz, PU-707A/M, September, 1977.

MIL-G-83380, Military Specification, Generator Sets, Gas Turbine Engine Driven, 30 and 60KW, 400 Hertz, February, 1979.

BIBLIOGRAPHY (CONT'D)

MIL-HDBK-217D, Military Handbook Reliability Prediction of Electronic Equipment, January 15, 1982.

MIL-M-4820E, Military Specification, Motor-Generator, Skid Mounted MD-4, July, 1979.

MIL-STD-471A, Military Standard, Maintainability Verification, Demonstration, Evaluation, March, 1973.

MIL-STD-490, Military Standard, Specification Practices, October, 1968.

MIL-STD-633E, Military Standard, Mobile Electric Power Engine Generator Standard Family, General Characteristics, February, 1980.

MIL-STD-705B, Military Standard, Generator Sets, Engine Driven, Methods of Tests and Instructions, June, 1972.

MIL-STD-721C, Military Standard, Definitions of Terms for Reliability and Maintainability, June, 1981.

MIL-STD-756A, Military Standard, Reliability Prediction, May, 1973.

MIL-STD-781C, Military Standard, Reliability Design Qualification and Production Acceptance Tests: Exponential Distribution, October, 1977.

MIL-STD-785A, Military Standard, Reliability Program for Systems and Equipment Development and Production, March, 1969.

MIL-STD-1322B, Military Standard, Definitions of Tactical, Prime, Precise, and Utility Terminologies for Classification of the DoD Mobile Electric Power Engine Generator Set Family, March, 1973.

MIL-STD-1408A, Military Standard, Air Conditioners, Family of Environmental Control Units, General Application Characteristics, April, 1975.

MIL-STD- 1650, Military Standard, DoD Standard Family of Aircraft Ground Support Power Units, June, 1974.

APPENDIX

SURVEY FORMS

F30602-81-C-0046

Generator Maintenance Data Survey

ORGANIZATION ______________________________

ADDRESS ______________________________

NAME/RANK ______________________________

TITLE/PHONE ______________________________

INITIAL INFORMATION	(Survey begins upon receipt of these forms.)
Nomenclature of Generator Set ____________	Serial Number ____________
Reading of Elapsed Time Meter at start of survey: A1 ________	A2 ________
Date of this reading ______________________	
If this generator set is unusual in anyway (in quality, usage, age, etc.), would you describe these distinctions on the back of this form. (Use comment label I1)	

FAILURE DATA (Information on failures and repairs should be entered on the separate FAILURE DATA form for generator sets.)

INSPECTIONS Date ____________ Meter readings: A1 ____________ A2 ____________

____________ ____________ ____________

____________ ____________ ____________

FINAL INFORMATION	(Survey ends on) ____________
Did this set fail during the survey? ________	Is FAILURE DATA attached? ________
Reading of Elapsed Time Meter at end of survey: A1 ________	A2 ________
Date of this reading ______________________	
Would you estimate how many times a week this generator set is started up................A1 ________	A2 ________
Both survival data as well as failure data is needed, so regardless of whether this generator set failed or did not fail during the survey period, complete this form with the final meter readings entered above. Thank you.	

PERFORMANCE INFORMATION

If the failure pattern observed during this survey is <u>not</u> typical of the ordinary performance of this generator set as known to you, would you describe the differences that come to mind on the back of this form. (Use Comment Label P1)

If the operating time accumulated during the survey period is <u>not</u> typical of the ordinary usage of this generator set, would you comment on the differences in usage that come to mind on the back of this form. (Use Comment Label P2)

> At end of survey,
> please hold forms for
> Jim Carey
> RADC/RBRAC
> Griffiss AFB, NY 13440

AUTOVON 8-587-4151

COMMENTS, OBSERVATIONS, PROBLEMS: (Use back of form.)

Reliability Analysis Center (RAC)
Generator Maintenance Data Survey

FAILURE DATA

Gen-Set Nomenclature______________________________

Gen-Set Serial Number______________________________

A failure of an engine generator set or a motor generator set occurs if:
It can't start after a few tries; or, it is shut down for repair during operation.
If a set continues to operate satisfactorily in support of its mission, it is not considered a failure

RELIABILITY INFORMATION	First Failure	Second Failure	Third Failure
R1. Date of gen-set failure........................			
R2. Reading of Elapsed Time Meter of failed set....			
R3. (Which generator set failed: A1 or A2) (A/E24U-8)			
R4. Did failure occur at start up or during operation?....................			
R5. Is this type of failure a significant problem on these gen-sets?....................			

MAINTAINABILITY INFORMATION			
M1. Actual Labor Hours for Time To Repair..........			
M2. Time Lost Awaiting Parts.......................			
M3. Briefly describe the nature of the failure/repair on the back of this form.........	M4/1	M4/2	M4/3

(Use these codes to label your comments.)

SYSTEM INFORMATION			
S1. Did failure occur during a PMI Test of the gen. set or during actual operation?................			
S2. What was the power load on the gen. set?........			
S3. Nomenclatures of systems receiving power.......			
S4. Were you able to switch over to another power source?....(Nomenclature?)...............			
S5. How long did it take to switch over?...........			
S6. If unable to switch over, why not?............	S6/1	S6/2	S6/3

(Use these codes to label your comments.)

COMMENTS, OBSERVATIONS, PROBLEMS: (Use back of form as needed.)

F30602-81-C-0046

Environmental Control Unit (ECU) Maintenance Data Survey

ORGANIZATION________________________________

ADDRESS________________________________

NAME/RANK____________________________

TITLE/PHONE____________________________

INITIAL INFORMATION (Survey begins upon receipt of these forms.)

Nomenclature of ECU________________ Serial Number____________

Nomenclature of System to which this ECU is attached ____________

Initial Reading of Elapsed Time Meter (if any)________________

Date of this reading____________________________

If this ECU is unusual in any way (in quality, usage, age, etc), would you describe these distinctions on the back of this form. (Use comment label I1)

FAILURE DATA

Information on failures and repairs should be entered on the separate FAILURE DATA form for ECUs.

FINAL INFORMATION (Survey ends)________________________

Did this ECU fail during the survey?________ Is FAILURE DATA attached?______

Final Reading of Elapsed Time Meter________________________

Date or estimated Hours of operation of this reading________________

Both survival data as well as failure data is needed, so regardless of whether this ECU failed or did not fail during the survey period, complete this form with the final meter reading entered above. Thank you.

PERFORMANCE INFORMATION

If the failure pattern observed during this survey period is not typical of the ordinary performance of this ECU as known to you, would you describe the differences that come to mind on the back of this form. (Use comment label P1)

If the operating time accumulated during the survey period is not typical of the ordinary usage of this ECU, would you comment on the differences in usage that come to mind on the back of the form. (Use comment label P2)

At end of survey,
please hold forms for
Jim Carey
RADC/RBRAC
Griffiss AFB, NY 13441

COMMENTS, OBSERVATIONS PROBLEMS: (Use back of form as needed.)

AUTOVON 8-587-4151

F30602-81-C-0046

Environmental Control Unit (ECU) Maintenance Data Survey

FAILURE DATA

ECU Nomenclature ________________

ECU Serial Number ________________

	First Failure	Second Failure	Third Failure
RELIABILITY INFORMATION			
R1. Date of ECU failure..........................			
R2. Reading of Elapsed Time Meter (if any)........ or Estimated Operation Hours Since Last Failure.			
R3. Did failure occur at start-up of ECU or during operation?..............................			
R4. Mode ECU operation? (Cooling or Heating)........			
R5. Is this type of failure a significant problem on these ECUs?..........................			

MAINTAINABILITY INFORMATION			
M1. Actual Labor Hours for Time to Repair...........			
M2. Time Lost Avating Parts.........................			
M3. Was this ECU actually repaired or *was another ECU substituted?*			
M4. Was this ECU actually repaired or was another ECU substituted?..................			
M5. (How long did it take to switch ECUs?)..........			
M6. Briefly describe the nature of the failure/repair on the back of this form.........	M6/1	M6/2	M6/3

(Use these codes to label your comment

SYSTEM INFORMATION			
S1. Did the failure occur during a PMI, Test of the ECU or during actual Operation of the shelter?			
S2. Did the electronic equipment in the shelter eventually have to be shut off or was it able to continue in operation during the ECU repair?			
S3. (How long was the electronic equipment off?)....			
S4. What was the outdoor temperature at the time of ECU failure, if known?.....................			
S5. How hot or cold did it get in the shelter?......			

COMMENTS, OBSERVATIONS, PROBLEMS: